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INTERNATIONAL INDUSTRY YEARBOOK

the encyclopedia of industrial progress

1948

Editor
LLOYD J. HUGHLETT

KRISTEN-BROWNE PUBLISHING COMPANY, INC.
NEW YORK, N. Y.

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Printed by New Era Lithograph Company, Inc.
New York, N Y

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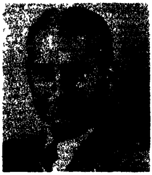
EDWARD H. BAXA

Author of numerous articles for the technical press, Mr. Baxa is an engineer in Allis-Chalmers' Basic Industries Department. He holds a chemical engineering degree from the South Dakota State School of Mines. He joined Allis-Chalmers in 1941 and is an active member of the Engineers' Society of Milwaukee

FRANK R. BENEDICT

Mr Benedict has been with Westinghouse Electric Corporation since 1928 when he received his electrical engineering degree. As a laboratory engineer he helped develop the high voltage cathode ray oscillograph for measuring lighting currents and voltages Subsequently he was engineer in charge of the Westinghouse Trafford Laboratories and the Impulse Laboratory At present he is Manager of the Industry Engineering Department of Westinghouse in East Pittsburgh, Pa.



MEADE BRUNET

Recently elected Vice President and Managing Director of the RCA International Division, Mr Brunet has been with RCA since 1921. An engineering graduate of Union College in 1916, he served in the U S Army Engineering Corps during World War I Prior to his present appointment Mr. Brunet was General Manager of the Engineering Products Department of the RCA Victor Division. He is a member of the Institute of Radio Engineers, Naval Engineers Society, Academy of Political Science and Sigma Psi, the honorary scientific society.

C. J. CARNEY, JR.

Managing Director of the Industrial Packaging Engineers Association, Mr. Carney has been associated with the I.P.E.A.A. since its inception. A graduate of DePaul University, he has worked with Hinde & Dauch Paper Company and Montgomery Ward & Co. on numerous projects involving industrial packaging as related to damage reduction, distribution economies and customer goodwill. At present he is engaged in promoting the formation of local chapters of the I.P.E.A.A. in the principal industrial areas of the United States

FRANCES HURD CLARK

Dr. Clark received her Doctor of Science degree in metallurgy from the Massachusetts Institute of Technology. During World War II she was consultant at the Frankford Arsenal and later was Assistant Professor of Metallurgy at the Stevens Institute of Technology. After working as chief metallurgist for the Western Union Telegraph Co, Dr Clark last year joined the staff of the A.R D. Corporation She has been doing research work for this company in precision casting and supervising the design of die casting equipment.

HOWARD COONLEY

Member of the Board and Chairman of the Executive Committee of the American Standards Association, he is also President of the International Organization for Standardization During an outstanding business career he has served as President of Walworth Company, President of the Boston Chamber of Commerce, President of the National Association of Manufacturers, Director of the Conservation Division of the War Production Board, Chief Advisor of the Chinese War Production Board, Deputy to Donald M Nelson, and Personal Representative of the President of the United States.

C. L. CROUCH

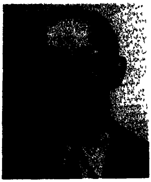
Graduate of the University of Michigan, Mr. Crouch has been associated with Holophane Co., Wipperman Mitchell, Inc, Buffalo Niagara Electric Co, and the Bureau of Ships, U S. Navy. At present he is Technical Director of the Illuminating Engineering Society and Advisor to the Illuminating Engineering Society Research Fund. Author of many papers relating to research in the illuminating fields, he was recently given the Niagara Award "for the best paper dealing with lighting application or studies."

AL. C. DOLEZAL

One of the charter members of the Industrial Packaging Engineers Association, Mr. Dolezal has had a quarter of a century's experience with the International Harvester Company in the packaging and materials handling field. Author of numerous training manuals on industrial packaging, he has acquired a recognized and authoritative knowledge of his subject from his wide range of activities in the fields of traffic supervision and industrial packing.

GUSTAF EGLOFF

An eminent leader in the chemistry of hydrocarbons and the cracking and refining of oil Author of nearly 400 articles and numerous books, he is also well known to the industry as a delegate to World Power Congress, World Engineering Congress, and Congress for Automobile Transportation He has been in his present position as Director of Research for Universal Oil Products Co since 1917.



R. F. FEIND

As a consulting engineer with Allis-Chalmers, Mr. Feind has been very active throughout Latin America where he served as coordinating engineer on many projects involving the design of plants employing crushing, cement and mining machinery He has designed much of the equipment presently used in the cement and rock products fields, including the largest jaw crusher ever built by Allis-Chalmers Mr. Feind is a member of the Engineers' Society of Milwaukee

HARRY L. FISHER

For many years Dr Fisher was Instructor in Organic Chemistry at Columbia University, and later associated with B F. Goodrich Co, U. S. Rubber Co., and General Laboratories. Since 1936 he has been Director of Organic Research for U S Industrial Chemicals, Inc. He is the author of over 30 patents, chiefly in the field of rubber as well as several books on rubber technology Dr Fisher is President of the American Institute of Chemists and was a recipient of a recent Modern Pioneer Award. He is also an active member of the Institution of the Rubber Industry, Great Britain.

DAVID L. FISKE

As a consulting engineer in New York City, Dr. Fiske has specialized in problems of air flow and humidity control in the low temperature field. For many years he edited *Refrigerating Engineering.* As Secretary of the American Society of Refrigerating Engineers, he was responsible for many professional projects in the field of research, education and standardization. He has written widely on all subjects of the industry from the thermodynamic properties of gases to the economic statistics of the refrigerating and air conditioning industry.

SAMUEL W. GIBB

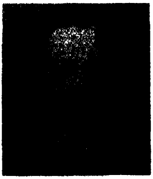
Mr. Gibb is President of the Materials Handling Institute and General Sales Manager of The Yale and Towne Manufacturing Co. After attending the University of Pittsburgh, he has spent 27 years in the materials handling field. He has won national recognition in his field and has contributed substantially to the new concept of selling materials handling equipment that is tailored to the individual plant's requirements and providing servicing and reconditioning facilities in the various industrial centers throughout the United States.

R. E. HANSEN

Following his graduation from Stevens Institute of Technology in Mechanical Engineering, Mr. Hansen joined Ebasco Services Inc., New York, in 1935 doing project studies involving power generation, air conditioning, the heat pump, and apparatus for utilizing electric energy. Subsequently he went with the Elliott Company, undertaking an engineering development project in the Marine Department.

ROBERT S. HENRY

Mr. Henry is Vice President of the Association of American Railroads. With a background in newspaper work and law, he entered the railroad service. With twenty-six years of work with railroads and directing public relations for the Association of American Railroads, Mr. Henry has become well known for his numerous books and articles on transportation and history.



JESSE E. HOBSON

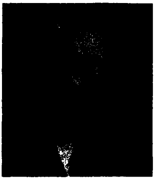
Until recently Dr. Hobson was Director of Armour Research Foundation of Illinois Institute of Technology. He is a graduate of Purdue University in Electrical Engineering and received his doctorate from California Institute of Technology. When with the Westinghouse Electric Manufacturing Co. he received the Eta Kappa Nu Award as "The outstanding young Electrical Engineer of the U. S." Dr. Hobson is a member of numerous scientific organizations, commissions, and technical committees. This year Dr. Hobson assumed his new post as Director of Stanford Research Institute, Stanford University, California.

A. H. HUBBELL

Holding an Engineer of Mines degree from the School of Mines, Columbia University, Mr. Hubbell has achieved a world-wide acquaintance in the mining profession. After graduation he worked with the Tennessee Copper Co Subsequently he went west, working in various capacities as mucker, machineman and timberman, millman, assayer and engineer at various properties in Colorado, New Mexico and Utah During his many years of association with *Engineering & Mining Journal*, his field trips have taken him throughout the United States, Mexico and Canada His many articles on mining progress are recognized as careful and authoritative studies of engineering in his field

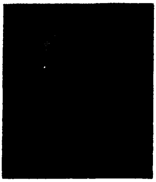
LLOYD J. HUGHLETT

Editor of THE INTERNATIONAL INDUSTRY YEARBOOK and Managing Editor of *Ingenieria Internacional Industria* and *Ingenieria Internacional Construccion* After completing his graduate studies at the University of Southern California, he taught physics and chemistry in Los Angeles Subsequently he joined the Cerro de Pasco Copper Corp. in Peru as Research Metallurgist In 1947 he edited "Industralization of Latin America," and served as Chairman of the Editorial Committee of the Engineers Joint Council's Commission on Latin America. He is also a director of the International Industrial Research Institute.



JULIAN S. JACOBS

Mr Jacobs is Editor of the *Textile Research Journal* He received his education at the University of Vermont and shortly after college became Vice-President in charge of manufacturing and sales for the John T. Slack Corp. Subsequently he became a textile consultant and dealer in textile raw materials In 1942 he joined the Textile Research Institute and became Director of Publications.

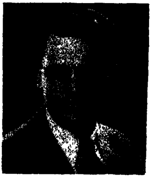


GORDON M. KLINE

Dr. Kline is the holder of degrees from George Washington University and the University of Maryland. He has held posts with the New York State Department of Health, Picatinny Arsenal, and, since 1929 has been with the National Bureau of Standards, he was made Chief of the Organic Plastics Sections of the Bureau which formed in 1935. As editor and writer Dr. Kline is well known in the plastics field. He is actively associated with various government committees and a member of numerous engineering societies

RONALD G. MACDONALD

Mr. Macdonald is well known throughout the paper and pulp industry. As Secretary of the Technical Association of the Paper and Pulp Industry (TAPPI) and Technical Editor of the *Paper Trade Journal* he has a daily and first-hand acquaintance with the industry. Holding degrees from Massachusetts Institute of Technology and New York University, he has been associated with Pejepscot Paper Co., Oxford Paper Co. and *Chemical and Metallurgical Engineering*. Mr. Macdonald is an active member of Inter-Society Color Council, American Chemical Society, American Institute of Chemical Engineers and numerous other societies.



GLENN H. McINTYRE

After graduation from Stanford University and the completion of his graduate studies at Western Reserve, Dr McIntyre joined Pike and West Shortly afterwards he went with Ferro-Enamel Corporation and in 1934 he became the company's Director of Research and recently he was elected Vice-President in charge of Research Dr. McIntyre is very active in both the American Chemical Society and the Ceramics Society. He is the author of numerous articles in his field of specialization

ED. C. POWERS

As Educational Director for the Compressed Air and Gas Institute, Mr. Powers has been active in the fields of industrial development and public service since his graduation from Amherst College in 1926. Besides being counsellor on Public Relations for several industrial concerns, he has been director of information services for several technical associations and institutes.

ANDREW E. RYLANDER

Technical editor of *The Tool Engineer*, Mr. Rylander brings to his writing thirty years of experience in industrial and tool engineering, design of automatic machinery, and the improvement of production methods. He is very active in several engineering societies and is President of the Swedish Engineers Society. Author of numerous patents and articles on metalworking, Mr. Rylander is an accepted authority in the machine tool industry.

GEORGE G. SWARD

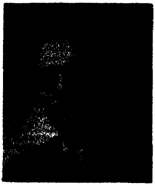
After graduating from the University of Iowa, Mr Sward worked with the National Bureau of Standards for several years He joined the Scientific Section of the National Paint, Varnish and Lacquer Association in 1926 He is a member of the American Chemical Society, American Institute of Chemists, American Society for Testing Materials, Society of Chemical Industry and the Forest Products Research Society. He is the author of numerous technical papers on paint, varnish and related subjects

T. L. SWENSON

Dr Swenson, food chemist and bacteriologist, is the author of over 80 publications and patents After receiving advanced degrees in food bacteriology and biochemistry, he became associated in a number of administrative and research positions with industry and the United States government. Until recently he was with Stanford Research Institute, Stanford University, as Director of Food Technology Presently he is organizing the Food, Chemical and Research Laboratories in Seattle, Washington

STEPHEN L. TYLER

Mr. Tyler is Executive Secretary of the American Institute of Chemical Engineers He was formerly with the Testing Department of New York, New Haven & Hartford Railroad, and the Thermal Syndicate, Ltd. Author of a large number of articles and patents in chemical engineering, Mr Tyler has been in close contact with the chemical industry over the last decade.



F. J. VAN ANTWERPEN

Editor of *Chemical Engineering Progress,* Mr. Van Antwerpen undertook his present responsibilities in 1946 when the journal was started by the American Institute of Chemical Engineers. Prior to his appointment he was Associate Editor of *Industrial and Engineering Chemistry.* Formerly he had been associated with the American Zeolite Corp., United Piece Dye Works, Munitex Corp., and a lecturer at Brooklyn Polytechnic Institute. Mr Van Antwerpen is very active in the Engineers' Council for Professional Development.

FRANK W. WILSON

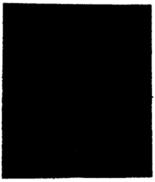
As Editor-in-Chief of the "Tool Engineers' Handbook," which will be published for the American Society of Tool Engineers during the forthcoming year, Mr Wilson has had an outstanding career in the field of industrial writing. A graduate in Industrial Engineering, he has been active as an editor and writer in many fields including the manufacture of electrical and generating equipment, textiles, food processing, and the coal and mining industries.

CARLETON F. WORFOLK

Schooled in engineering at Detroit University and the University of Michigan, Mr Worfolk has become a prominent figure in the metalworking industry. At one time he operated his own manufacturing plant Building combustion engines and transmissions, he was the first to utilize cast steel for combustion engine crankshafts. As Detroit's Chief of Ordnance during World War II he contributed his immense factual knowledge and experience to Detroit's capacity for mass-production He is the author of several publications in the metalworking field

J. PAUL YOUTZ

Chairman of the Industrial Design Section, California Institute of Technology, Mr Youtz is also Business Manager of the California Institute Research Foundation. Formerly he was associated with General Electric Co. and Vice President of Lojas General Electric, S. A. Brazil He is a member of the American Institute of Electrical Engineers, Illuminating Engineering Society and Sigma Xi.



VIN ZELUFF

For both his profuse writings in the field of Electronics as well as his practical knowledge concerning the installation, maintenance and manufacture of electronic equipment, Vin Zeluff is well known throughout his profession. Having taught radio and electronic theory for several years in New York, Mr. Zeluff joined the editorial staff of *Electronics*. He is co-author of "Electronics for Engineers," "What Electronics Does," and the forthcoming book, "Handbook of Industrial Electronic Circuits."

INTRODUCTION

The INTERNATIONAL INDUSTRY YEARBOOK is an annual publication planned to summarize the technological progress achieved in the various fields of engineering and industry It is intended to serve both management, education and the engineering profession by providing, in a single volume, the overall picture of the technical advancements throughout industry as a whole. This first issue of the Yearbook is not designed to accomplish a deep vertical penetration into a single field, but rather to provide a broad horizontal review of significant industrial developments.

The INTERNATIONAL INDUSTRY YEARBOOK is intended to fill a long felt need by offering in one volume the most significant and generally valuable progress reports from various fields as commonly represented by the technical societies and trade associations Highly specialized accounts of technical developments are presented in a clear, semi-technical language

A clearing house of general information on advances in industrial technology, which the INTERNATIONAL INDUSTRY YEARBOOK is intended to be, has been recommended by many who are unable to follow the large number of trade and professional magazines that directly or indirectly relate to their particular fields To condense, in readable style, the important and salient technical developments described in specialized engineering studies, magazines, convention reports, etc , and present them in an understandable form to industry as a whole is the primary function of this Yearbook.

Due to the cloak of wartime censorship, full publicity has not been given to many advances which stem from research during the period of world conflict. Accordingly, the various contributors to this 1948 Yearbook have traced back certain developments in order to bring industrial engineering progress up-to-date This review, spanning the last half decade, has necessarily compelled the various authors to omit many details and descriptive information that will ordinarily be included in future issues.

It has become a truism in recent years to speak of the interdependence of nations. It is also becoming apparent that there is an increasing interdependence of technological knowledge between various engineering fields. It is the objective of the INTERNATIONAL INDUSTRY YEARBOOK to promote the flow of technology not only within countries but across national boundaries as well. No single field of engineering or research can be developed independently. This becomes increasingly evident when industrial changes and technological developments are being accelerated in all parts of the post-war world.

An effort has been made through this Yearbook to emphasize the transference of data and information between various fields of industry so that they can be used advantageously and quickly. It is often forgotten that the transfer of developments from one industrial field into others is an economic necessity. There are certain common elements in materials and equipment that may be assimilated advantageously by fields other than those in which they were originally developed. Accordingly, each contributor has written his specific review article from the viewpoint of its relation to industry as a whole. Each review not only relates the specific developments in its field, but also describes the expanding use for these end-products by other industries.

No single man can be conversant with developments throughout all of industry; often he is not fully aware of the significant progress achieved in his own special field. Yet management is faced with the responsibility of *understanding and acting upon* trends throughout industry as a whole. This can only be achieved through a collaboration of experts in each field of industry who write directly and in a basic engineering language. Their reviews, as published in this single volume, provide the broad engineering profession, educators, economists and business management with a valuable tool for integrating and evaluating the impact of recent industrial change.

In this issue we have touched only lightly upon the developments in countries outside the United States. It has been felt that the greatest progress in engineering and technology during rcent years has been achieved here rather than in other countries In the coming and subsequent issues, however, greater emphasis will be given to a more penetrating coverage of world-wide technical progress.

The subjects included in the 1948 Yearbook have been chosen to include the most significant developments in the major fields of industry. Such a selection is highly correlated with those fields which have been most stimulated by wartime research. This broad coverage reviews in major outlines the progress of several years in fields which are of special interest to business and industrial management.

The text of each article serves to review the developments and trends inadequately reported elsewhere, as well as to summarize much that has been published in the field. These functions are, in turn, carefully supported, point by point, with the necessary bibliography and reference materials. The interpretation of trends has been left to the discretion of each contributor. Economic discussions have been avoided except insofar as they were judged to be essential to an understanding of the technology involved in any given field. Since the Yearbook is primarily intended as a technological review, economic evaluations and interpretations are judged as largely secondary to the fundamental intentions of the Yearbook.

The success of such an ambitious project as this single-volume review of industrial progress depends in no small measure upon the competence and responsibility of the contributing authors. A glance at the backgrounds of the men selected to write for this Yearbook, as described in the previous pages, will indicate their authority and recognized position in their chosen fields. The conciseness and clarity of text, well organized exposition and highly refined bibliography reflect the thoroughness of their work.

As editor of the Yearbook I would like to express my personal appreciation for the cooperation and kindly efforts of everyone involved in making this volume a reality.

L. J. H.

CHAPTER I

WORLD INDUSTRY

by LLOYD J. HUGHLETT

A survey of world industry is at any time an extremely hazardous and bewildering undertaking With the world technically at peace, but with war engaging the efforts of millions of people in Asia and the Middle East, and with parts of Europe disrupted more than two years after the end of war, such a survey as that of the INTERNATIONAL INDUSTRY YEARBOOK must recognize the limitations of available information.

It is impossible to obtain either reliable or valid data from many countries It is under any circumstances impossible to obtain adequate information from some countries at any time. Many nations are not yet equipped to collect and report such statistics. This survey, therefore, has been restricted to the principal industrial nations of the world and the reader will discover that the details of the individual reviews are roughly commensurate with the importance of each nation. It is our intention to make annual reports upon these countries, supplementing them with studies upon countries of secondary industrial importance when sufficient pertinent data becomes available

In the absence of completely comparable data and classifications for all nations, it has been necessary to include the most nearly comparable series of statistics. Some countries have classified different industries under customary categories Whenever this is true, it has been noted. Where all data for a country are given in metric values, we have decided not to alter them This is particularly significant in the instance of industrial targets, since the translation of a rounded target to another system would result in what would appear to be a specific figure, e.g., a coal production of 250 million metric tons would appear converted as 275,377,500 U. S. tons.

Where a series of figures has been included to demonstrate a trend, and the units of measurement are of an unfamiliar local nature, they have been left unchanged, with an indication of what the units mean in more familiar terms. Wherever it has been impossible to obtain recent (post-war) statistics, we have included the latest pre-war figures rather than omitting them entirely. For the large part monetary values have been converted to dollars except as otherwise specified With few exceptions, statistical material has been obtained from official government sources.

The Editor

WORLD INDUSTRY SINCE THE WAR

More than two years have elapsed since the technical termination of the World War II These years have witnessed a general decline in the world's industrial activity from the peak attained at the height of the war Two important industrial powers—Germany and Japan—have been crushed by defeat Their industry has been controlled by the occupying authorities pending major decisions relating to its eventual disposition through reparations and its permissible peacetime level.

The recent war is directly responsible for the worldwide shortages of food, fuel, and raw materials Planned destruction crippled much of Europe's industry. Wartime neglect has left a mark on what productive facilities remain. Dislocations of trade further hamper the rebuilding of supply lines and the distribution of goods. The peoples of the warring nations of Europe have been decimated, and those who have survived are discouraged and suffering from malnutrition. It is impossible to measure the psychological handicaps which retard recovery, yet they most certainly affect the pace of reconstruction.

First measures to revive liberated economies were taken by the Allied armies Emergency relief was provided by the military under a program designed to prevent "disease and unrest" behind the advancing troops Wherever possible and useful, liberated industry was put to work on military contracts—manufacturing finished munitions and spare parts for military equipment, and otherwise aiding the war effort Some countries were thus enabled to earn hard currencies and to put men and machines back to work

Long before the end of the war, the United Nations Relief and Rehabilitation Administration initiated the procurements of foods and materials for reconstruction in liberated areas. Funds made available to UNRRA for operations which came to an end in 1947 amounted to nearly 4 billion dollars, of which more than 70 per cent was provided by the United States. An important function of UNRRA in liberated countries was the supply of industrial equipment and farm machinery to accelerate industrial and agricultural recovery.

Once the war had been won, the victors were forced to assume responsibility for the defeated nations Vast sums have been expended by the occupying powers to maintain order and a minimum level of economic activity The cost to the United States has exceeded a billion dollars a year, and for 1948 a sum of $1,090,000,000 has been requested to cover occupation costs in Japan and Germany France, Great Britain, and the Soviet Union have assumed a lesser expense in the areas they occupy

Since the war, Europe has obtained foreign credits amounting to more than 14 billion dollars, and devastated areas in the Far East have received 730 million dollars The United States provided 58 per cent of these funds, and other hard currency nations have supplied the rest Nearly 75 per cent of United States dollar credits have been allocated to two countries the United Kingdom and France The following table compiled by the United Nations Economic and Social Council summarizes the credits obtained by devastated countries from May, 1946 to the middle of 1947, as evaluated in U S dollars

Country	*Amount (Millions of $)*
Austria	45
Belgium	307
Bulgaria	4
Czechoslovakia	168
Denmark	272
Ethiopia	6
Finland	180
France	3,261
Greece	151
Hungary	37
Italy	462
Luxembourg	12
Netherlands	898
Norway	215
Poland	169
Romania	—
U S S R	523
United Kingdom	7,325
Yugoslavia	2
China	285
India	—
Siam	25
Burma	125
Philippine Islands	81
Indo-China	—
Netherland Indies	215
Total	14,768

United States government credits accounted for $8,024 million dollars derived from the following sources.

Source of Credits	*(Millions of $)*
U. S. Surplus Property Credits	1,134
Export-Import Bank	2,048
Maritime Commission	133
Terminal Lend-Lease Credits	959
U. S. Loan to the United Kingdom	3,750

Private bank loans and bonds floated on the American market supplied several hundred million dollars more Canada, the United Kingdom, Sweden, Switzerland, and Argentina have granted substantial credits to European countries In addition, payment agreements between liberated countries have made possible short-term credits to cover deficits in trade accounts

Two major projects initiated in 1947, aimed at securing the peace and restoring world economy, have been the United States program for aiding Greece and Turkey and the Marshall Plan for European recovery, including its extensions to the Far East

Both undertakings unhappily but necessarily reflect the underlying rivalry between the East and the West To varying degrees they have ideological as well as military significance Of the 300 million dollar appropriation for Greece, 50 per cent has been allocated for military purposes Of the 100 million dollars earmarked for Turkish aid, the entire amount was intended for "purposes of increasing mobility, balance, fire-power, other modernizations, and decreasing the manpower requirements of the Turkish armed forces ."

In mid-1947, Secretary of State George C Marshall outlined a plan for economic aid to Europe and invited all European countries to present estimates of their needs budgeted over the next several years Sixteen nations of western Europe responded to the invitation The countries of eastern Europe, charging that the plan constituted a form of American dollar imperialism and infringed the rights of sovereign states, refused to participate

The Committee for European Economic Cooperation met in Paris and drafted a plan which was submitted to the United States The staggering conclusion of the conference was that Europe would need 20 5 billion dollars in goods and services from the United States over a four-year period, for which it could plan to offer in return goods and services valued at 4 7 billion dollars Requirements for 1948 were estimated to total 6 05 billion dollars.

The immediate reaction to the European Recovery Program in the United States was a request to Congress for funds to cover interim aid amounting to nearly 500 million dollars, pending careful study of the long-term aid program. It was obvious, from the outset, that Europe's requests would be scaled down.

Nevertheless, the broad lines of the recovery plan provide a clue to the problem and how the sixteen nations propose to solve it In the first place, Europe wants to duplicate an expansion that parallels the growth which occurred in the United States during the war years, 1940-44 In that period, U S production rose as follows: coal, 34 per cent; steel, 31 per cent; and electric power, 61 per cent. The parallel European goals are: coal production, to increase 33 per cent; steel (excluding Germany), to increase 60 per cent; and power, to increase 39 per cent.

The Committee for European Economic Cooperation outlined the reasons for Europe's needs as follows:

1.) Physical devastation and disruption in western and eastern Europe's principal food and timber pro-

ducing zones, together with the dislocation of the European transportation system, caused a temporary paralysis in western Europe, including Germany;

2) Prolonged interruption of international trade has occurred simultaneously with the loss of income from merchant fleets and foreign investments. This has contributed to the exhaustion or diminution of dollar funds in the sixteen countries. This has occurred at a moment when many vital needs could be met only from dollar resources,

3) Human strain and exhaustion are the results of six years of war or enemy occupation,

4) Their international financial disequilibrium is the inevitable result of a long war,

5) In southeast Asia, the shortage of food supplies and raw materials are vital to the European economy, both for direct consumption and as earners of dollars,

6) The abnormal increase of population in certain areas is a consequence of the wartime movement of peoples.

These are the handicaps to recovery, and in drafting a plan to overcome them, each of the sixteen nations pledged:

1) To develop its production to reach the targets, especially for food and coal,

2) To make the fullest and most effective use of its existing productive capacity and all available manpower;

3.) To modernize its equipment and transport, so that labor becomes more productive, conditions of work are improved, and standards of living of all peoples of Europe are raised,

4) To apply all necessary measures leading to the rapid achievement of internal monetary and economic stability while maintaining in each country a high level of employment,

5.) To cooperate with one another and with like-minded countries in all possible steps to reduce tariffs and other barriers to the expansion of trade both between themselves and with the rest of the world, in accordance with the principles of the draft charter for an International Trade Organization.

6) To remove progressively the obstacles to the free movement of persons within Europe:

7.) To organize together the means by which common resources can be developed in partnership.

The goals established by the Committee for European Economic Cooperation have been summarized as follows.

1.) Restoration of pre-war bread, grain and other cereal production, with large increases over pre-war production of sugar and potatoes, some increases in oil and fats, and as fast an expansion in livestock as supplies of cattle feed will allow;

2.) Increase of coal output to 584 million tons, i e, 145 million tons above the 1947 level (an increase of one-third) and 30 million tons above the 1938 level;

3.) Expansion of electricity output by nearly 70 billion kwh or 40 per cent above 1947, and an increase in generating capacity by over 25 million kw or two-thirds above pre-war;

4) Development of oil refining capacity in terms of crude oil by 17 million tons, or two and one-half times the pre-war level,

5) Increase of crude steel production by 80 per cent above 1947 to a level of 55 million tons or 10 million tons (20 per cent) above 1938,

6) Expansion of inland transport facilities to carry a 25 per cent greater load in 1951 than in 1938.

PRODUCTION OF BASIC FOODS

(millions of metric tons)

Commodity	*1934-38 Average*	*1946-47 Average*	*1947-48 Average*	*1950-51 Average*
All cereals	64.5	55.6	48.9	65.8
Bread grains	34.0	28.3	21.4	34.0
Potatoes	57.7	50.7	61.6	68.2
Sugar	3.4	3.3	3.4	3.9
Meat	9.0	5.9	6.0	8.1
Milk	72.5	55.7	57.0	73.4
Oil and fats (including butter)	2.8	2.0	2.2	2.9

PRODUCTION OF COAL AND LIGNITE

(millions of metric tons)

Country	*1938*	*1947*	*1948*	*1951*
United Kingdom	231	199	214	249
Western Germany Bi-Zone	206	133	149	193
Saar	14	10	14	17
France	48	51	51	63
Belgium	30	24	26	31
Other countries	23	22	24	31
Total	552	439	478	584

PRODUCTION OF CRUDE STEEL

(millions of metric tons)

Country	*1938*	*Best Year*	*1947*	*1948*	*1951*
United Kingdom	10.6	13.2	12.7	14.0	15.0
France	6.2	9.7	5.8	10.4	12.7
Belgo-Luxembourg	3.8	7.0	4.6	7.3	7.9
Italy	2.3	2.3	1.6	2.5	3.0
Other countries	1.8	1.8	2.0	2.3	4.1
Bi-Zone of Germany	17.8	17.8	2.8	4.1	10.0[1]
Saar and French Zone	3.0	3.0	0.8	1.7	2.7
Total	45.5	54.8	30.3	42.3	55.4

[1] Limited in 1947 to 4.7 million ingot tons, but the occupying authorities are considering an upper limit of 10 million to 12 million metric tons.

Eastern Europe voluntarily excluded itself from the scope of the Marshall Plan. These countries on the periphery of Russia's borders showed a political affinity to the Soviet Union, and are faced with their own difficult economic problems. They may, in time, request financial aid from the United States. So may the Latin Americas, for whom it has been formally suggested that the Marshall Plan be extended. And for the Far East, at some later

STATUS OF ELECTRIC POWER CAPACITY

PRODUCTION AND DEFICITS

(Marshall Plan countries and Western Germany)

	1938	*1947*	*1948*	*1949*	*1950*	*1951*
Power capacity (million kw)	39.0	—	48.7	54.2	59.6	65.5
Increase over previous year	1.5	—	4.7	5.5	5.4	5.9
KWH produced (billions)	130	170	189	206	222	237
Capacity deficits (per cent)	—	17	15	14	11	8
Production deficits (per cent)	—	5	4	4	3	2

date, a similar United States program of economic aid has been proposed.

Eastern Europe was occupied by the Red Army. The "liberated" governments in the states bordering the Soviet Union have linked their national economies to the U.S.S.R. and to their neighbors. Throughout this block of countries in eastern Europe, the first bilateral trade agreements were reached after the war. These have since been so interlaced and extended that the area has become dependent upon itself and the Soviet Union to a degree never before attained. A part of this trend has been caused by the loss of Germany as a principal trading partner. But the dependence upon bilateralism in trade was a resurrection of a pre-war, post-depression technique largely impelled by unstable currencies and lack of usable foreign exchange resources. Bilateralism has not been confined to eastern Europe, although it is more prevalent there, but has characterized European trade as a whole since the war. More than 150 such agreements were concluded within the first two years following the war.

In most countries of eastern Europe strong centralized governments have evolved. Although many countries of Europe had placed railroads, banks, power, communications and other economic factors under government control long before the war, in eastern Europe national economic plans required the nationalization of most basic industries. Only small factories and services have been left in private hands. Foreign trade has been vigorously controlled by government.

Although eastern Europe, with the help of the Soviet Union, has been less affected by the crisis in food supply because it has been traditionally a food-surplus area, its industrial recovery has been slowed by lack of funds with which to obtain capital equipment from the major western European and American suppliers. In general, the rate of recovery and the present level of production is about the same as in western Europe.

The Far East has remained in turmoil. War between the Central Government forces and the Communist Government of northwest China broke out soon after the defeat of Japan. It was continuing on an alarming scale at the end of 1947. Chinese economy is in chaos and there is little hope of recovery as long as militarism engages so predominant a share of the nation's energy, materials, and finances. India, too, was torn by civil strife immediately after partition, and industrial activity declined throughout 1947.

Problems of supply harassed every war-afflicted nation. Because stocks of food and materials were depleted by the war, and industrial facilities were either destroyed or neglected, imports out of proportion to pre-war levels have been required to permit recovery of any kind. The war left most nations without the money to purchase goods, even where transport facilities were available to carry them. Many countries which had traditionally depended upon their merchant fleets to correct adverse balances of trade suffered heavy shipping losses. United States loans and credits have gone far to assist these nations, but acute shortages of the most essential commodities—coal, food, steel, and machinery of certain kinds—have been long delayed in delivery even when money has been available.

This circumstance has led to a general impression that international trade in the post-war years has lagged far behind the pre-war level, except on the part of such major suppliers as the United States, Great Britain and Canada, which have experienced foreign trade booms. Certainly during the first post-war year, international trade was at a low level. But in the second half of 1946, and throughout 1947, trade climbed steadily, and in some instances spectacularly.

The Bank of International Settlements has summarized the status of post-war trade in its Seventeenth Annual Report. Figures are given in United States dollars, and in the table shown at the top of the opposite page no attempt is made to make adjustments for the known rise in the costs of goods moving in international trade.

From this table it can be seen that in the 12-month period from June, 1945 to July 1, 1946, the dollar volume of trade surpassed the levels of both 1937 and 1938, and in 1946 was more than half again as large. For comparison with prewar conditions, it is necessary to try to strike an average for the probably price rise between 1938 and 1946. In this connection, the B.I.S. points out, trade figures have been converted to dollars at the official rate of exchange and in many countries the domestic price rise was steeper than in the United States. Moreover, the value of imports has been swollen by the heavy cost of shipping. If the level in 1938 is taken as 100, the price index figure for the latter half of 1946 would probably be somewhere between 200 and 250. If calculations are made on the basis of a price index figure of 225, the volume of 1946 trade would appear to be only about 10 per cent below the 1938 volume.

(in millions of $)

	1929	*1937*	*1938*	*1945 July-Dec*	*1946 Jan-June*	*1946 July-Dec.*	*1945-46 July-June*	*1946 July-June*
	12 months			*6 months*			*12 months*	
United Kingdom	15,200	7,300	6,500	3,300	4,100	5,000	7,500	9,100
United States	16,100	6,300	5,000	5,800	6,900	7,400	12,700	14,300
31 Other Countries	36,300	16,900	14,600	9,100	10,300	14,200	19,400	24,500
Total, 33 Countries	67,600	30,500	26,100	18,200	21,300	26,600	39,600	47,900

Applying this yardstick to the recorded trade of twelve nations in Europe (as reported by the United Nations economic section), after eliminating non-commercial imports (chiefly UNRRA), it would seem that 1946 trade was 87 per cent of the 1938 volume In 1947, from estimates of full-year trade prepared several months before the end of the year by twelve governments, trade may have exceeded the 1938 volume by between 10 per cent and 20 per cent However, a preponderance of imports alters the optimistic picture which figures tend to depict Most devastated countries are forced to accept the prospect of a continuing deficit in their trade accounts for the next three to five years

Nevertheless, world recovery depends heavily upon a rising trend in the exchange of goods between nations In the fall of 1947 the 18 chief trading nations met at Geneva to discuss the draft charter of the International Trade Organization After six months of persistent effort, agreement on most points had been reached, and a vastly complex system of tariff reductions had been tentatively agreed upon—pending approval of many of the participants The Charter aims directly at reducing barriers and restrictions to world trade, thereby making possible an expanding volume of multilateral commerce

ARGENTINA

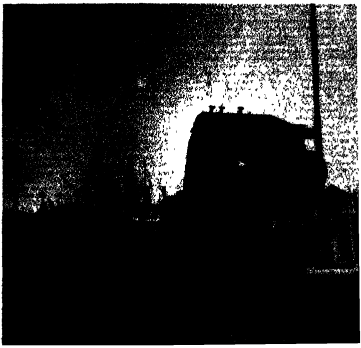
The *Pampa*, constituting some quarter of a million square miles, is Argentina's agricultural, manufacturing and population center During the last ten years the nation has made tremendous strides towards establishing certain industries throughout this area that will make the country independent of outside sources of supply. The country has a well developed though agriculturally dependent industrial system. By 1947, Argentina was processing about 85 per cent of its total agricultural production. Although exports consist predominantly of livestock products and grain, they are now being shipped abroad as processed goods.

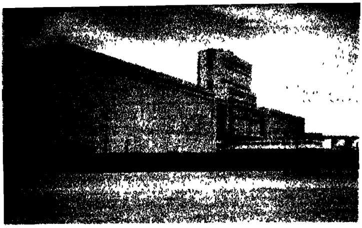
Argentine resources lack certain important sources of supply for a fully self-sufficient and advanced industrial economy. Coal, hydro-electric power immediately accessible to population centers, and high-grade and workable deposits of iron are outstanding deficits in the country's economy.

During the war Argentina enjoyed a new high in foreign trade which under the present political management of the country has indirectly contributed to the national-

After opening new plant in Mexico (above) E. R. Squibb & Sons are now expanding in Argentina with a new plant to manufacture a large variety of pharmaceuticals.

Power demands of Argentina require imports of heavy power generating equipment. With top priority it moves quickly through Buenos Aires' congested port.

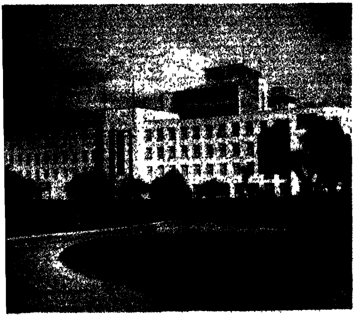




Huge terminal elevator in Buenos Aires, with a capacity of 150,000 tons, stores grain from the Pampa for overseas markets.

One of the new Duperial Chemical Co.'s plants constructed outside of Buenos Aires. It will increase number of new Argentine products.

New building of Philips Argentina. This company employs 2,000 workmen for manufacturing electrical equipment.



ization of industry The government's efforts either to enter into a partnership with private enterprise or to control industry indirectly has been intensified in recent years The government has organized, owns, and operates industrial plants and agencies to compete with companies operating under foreign capital. The purchase of foreign-owned utilities has occurred with regularity over the past five years.

In 1947 the census of those gainfully employed by industry was somewhat over a million workmen, which represents an increase of slightly over 100 per cent during the last 10 years. Refugee technicians and engineers from Europe have contributed substantially in providing the technical know-how for creating new manufacturing plants and expanding the old-line manufacturing companies which have supplied many of the basic commodities sold on the Argentine market

Despite the fact that Argentina is not highly industrialized by U. S standards, industry now accounts for about 46 per cent of the national income This means that it has now surpassed agriculture and livestock in the Argentine economy

Great strides have been made in the chemical processing industries Duperial Chemical Co. has been particularly outstanding in this field, and has installed new equipment in its Buenos Aires plant for the manufacture of rayon and nylon

Industrial progress has been hampered by shortages in domestic ores and fuels Despite this, the government has pushed a number of projects in this industry Armco International for example, has been given a contract for a new steel mill, at a cost of 100 million dollars Eight new hydro-electric projects are planned for this year In addition many smaller plants have been constructed in the area about Buenos Aires for the manufacture of such products as refrigerators, batteries, tires, phonographs and pharmaceuticals.

Argentina does not intend to let the fledgling industries made possible by war die out nor do the country's plans as envisaged by President Juan D. Peron anticipate allowing the nation to revert to a predominantly agricultural-pastoral economy characteristic of the years before World War II

Argentina's program for developing its industries has been expressed in the comprehensive five-year plan of President Peron as presented to the Argentine Congress on October 21, 1946 Although there have been disappointing cutbacks in the objectives outlined in the original series of 27 bills, the plan nevertheless provides a definite, blueprinted schedule for the broad economic development of the country at a total cost of $1,665,-000,000 (U.S cy.). Financial backing for the plan is to be furnished by government exports. Record prices for Argentine grains have been negotiated by Miguel Miranda, Director of Economic Affairs.

Principal features of the 1951 goals of the five-year plan include: a 48 per cent increase over 1943 averages in the value of goods to be processed, a 52 per cent increase in wages, a 54 per cent increase in employment, and a 50 per cent increase in motive power.

Manufacturing goals have been set quite high and it is not likely that they will be met according to the schedule as originally planned. Specific items to be expanded are enumerated in the following table. However, technical difficulties, unfavorable balances of trade with countries capable of supplying the industrial equipment needed, and difficulties in persuading foreign capital to back private enterprises in Argentina are factors likely to curtail many of the projects.

MANUFACTURING GOALS

Products	*Present Output Metric Tons*	*Output by 1951 Metric Tons*
Cotton yarns	63,000	80,000
Woolen yarns	21,500	30,000
Rayon yarns	4,500	8,000
Argentine long-fiber yarns	4,000	6,000
Silk yarns	2	300
Printing paper and other paper	100,000	190,000
Newsprint	—	50,000
Wool scouring	65,000	100,000
Caustic soda	10,000	40,000
Sodium carbonate	—	25,000
Lead arsenate	—	500
Barium chloride	500	800
Citric acid	150	400
Minium	650	1,000
Zinc oxide	1,400	3,500
Steel blooms	120,000	315,000
Lead	22,000	24,000
Zinc	2,000	6,000
Tin	850	2,600
Antimony	1,100	2,000
Aluminum	1,200	1,400
Tin Plate	—	70,000

Under the state controlled five-year plan, various sources of raw material, as well as the semi-finished goods, will fall under the broad discretionary powers of the government. This will place private concerns under indirect control of the state in the utilization of raw materials. The raw materials and the semi-finished goods enumerated below will in all likelihood be subject to State control. Largely consisting of agricultural-pastoral products, they constitute the basis for several of the country's principal exports. Further efforts in the country's industrialization program will be directed towards processing these supplies into finished goods.

RAW MATERIALS

Foodstuffs and Oilseeds Wheat, oats, rye, barley, rice, corn, cotton, sunflower seed, linseed, peanuts, grapeseed, spurge

Farm Products Hides, skins, wools, cotton and linen fiber, hemp, ramie, parmio, jute

Forest Products: Timber of several kinds

Mineral Products· Solid and liquid fuels, metallic minerals, containing iron, copper, lead, tin and zinc

SEMI-PROCESSED GOODS

Foodstuffs and Oils. Flours and oils of all kinds.

Farm Products: Tanned leather and skins, yarns, ropes, fabrics, and paper.

Forest Products: Tanning extracts, semi-manufactured timber of all kinds, derivatives from wood distillation.

Mineral Products: Pig iron, copper, lead, tin, zinc and alloys; rolled or cast materials manufactured therefrom; products derived from the industrial processing of fuels; lime and cement.

Under the U S plan for European recovery, large sums will be spent in Latin America for the purchase of foodstuffs to be shipped to France and Italy. Unquestionably Argentina will be the principal Latin American contributor of grains and beef. It is anticipated that U S. dollars will be made available to Argentina for the purchase of the machinery required under the five-year plan. Government controls are in tight effect to channel all imports into those fields which support the industrial development of the country. In May, 1947, Argentina's balance of trade was unfavorable for the first time in over five years. During the first six months of 1947, U S sales to Argentina were about 300 million dollars as compared with Argentine exports to the United States of 90 million dollars. This lopsided traffic has seriously affected the country's dollar balance, although it is still in a sound and strong position.

Much of the industrial machinery and certain raw materials will be admitted duty free into Argentina as a means of encouraging the industrial five-year plan. Products which compete with the national industries will not be given import permits. Furthermore, government purchasing agencies will favor Argentine products even if they do not compare in quality with the imported goods. Supplemental measures to support the development program will include stockpiling of materials required by manufacturing industries, price fixing of certain raw materials, government subsidies to promote Argentine industry, and protective tariffs.

Peron has recalled that only two decades ago Canada and Argentina were approximately equal in their manufacturing capacity. Today Canada, with a population smaller than Argentina's, has almost tripled its industrial capacity. To accomplish the first step in the five-year program, the government is not engaging in the construction of a large number of factories, but rather is adopting a schedule for improving the basic industrial facilities of the country such as transportation, power, etc.

This includes the purchase of much needed rolling stock, modernization and rehabilitation of railroads. Highway transportation and aviation will also be improved at a budget of around 32 million dollars a year. River transportation will be developed to support the growing merchant marine. Both the Rio Negro and the Parana will be dredged in certain locations and port installations improved. Port facilities at La Plata are exceptionally congested and docks are loaded with industrial equipment purchased and delivered but not shipped to their point of installation.

The five-year building program has been set at a total of 155 million dollars. Approximately half of this total has been tentatively allocated to educational facilities for 300,000 students of all levels. The second large portion of the building funds will be used to construct about 300 government office buildings. Other buildings to be erected include national-park tourist hotels, terminal grain and field storage elevators, low cost housing, and a series of dams in the western provinces which will be coupled with a farm colonization program in that area.

Electric power continues to be the key to any industrial expansion pipe line connecting the oil fields at Comodoro Rivadavia with Buenos Aires. This line will represent the axis of industrial development. The bulk of the pipe was bought in Italy with iron being supplied by the United States. The construction of a large hydroelectric project at Salto Grande is still in the discussion stage. At present only about 5 per cent of the country's power is derived from hydro, 12 per cent from diesel, and 83 per cent from steam. Looking beyond the five-year plan, Peron has proposed that the country increase its hydroelectric potential from its present 45,000 to 1,400,000 kwh in fifteen years.

Many delays will be experienced in executing the various ramifications of the five-year plan Principal of these will be due to the need for competent coordination. A large share of the projects exist in name only Very little work has been done on many of them and only a few are being worked out in full engineering detail. Construction has been started on still fewer of the undertakings. Nevertheless, the five-year plan is fully entrenched in the minds of the Argentines The country has a planned objective towards which it is bending its entire financial and moral resources With a well fed, clothed and educated population, the country will unquestionably succeed in achieving a great many of the industrial goals which have been defined.

Modern equipment characterizes the new 8 million dollar Beccar plant of ADOT. Latest fireproofing and lighting designs are employed.

Plant and company town of the Samper Cement Co., near La Calera, 40 miles north of Bogota, Colombia.

With 10 years operation in Argentina, Eveready Battery Co. has undertaken a large expansion program. Located in suburb of Buenos Aires. It manufactures a large variety of products.

AUSTRALIA

Since the end of the war, Australian industry has been concentrating on the job of consolidating gains made during the war years Planning and developing post-war industry have, therefore, been directed toward full use of new skills, materials, and trained labor, decentralization of industry throughout the Commonwealth, and use of government facilities and equipment by private businesses

Australia made rapid progress in industrialization after the depression. Manufacturing production rose in value from 385 million dollars in 1932-33 to 657 million dollars in 1938-39 During the war years, the value of production rose 78 per cent to 1,170 million dollars in 1945-6 These figures include, of course, a rise in prices over the periods covered

In 1943, before the end of the war, the Commonwealth Secondary Industries Commission was established to review manufacturing progress and recommend post-war development policies to the government. The vastly increased production was accomplished by expanding facilities War factories had risen in number from five to 42, over 220 new machine shops and annexes had been established for industry; privately-owned factories had increased by over 2,000; shipyards, airdromes, and transport facilities had been built and extended; and new raw material resources—chiefly coal, iron-ore and nonferrous metal deposits—had been developed. In 1944 the Commonwealth Secondary Industries Division was set-up to implement industrial expansion plans of the government.

Assistance to private manufacturing by both state and central governments has been a feature of post-war industrial development. Of the 42 modern war plants built and equipped by the government, 33 have been reconverted for use by private industry. Of these, 22 are in rural areas and 11 are adjacent to large industrial towns. An effort has been made to decentralize new production facilities to utilize local sources of raw materials, labor, water, and power. As a result, some 214 new enterprises covering 39 industries have acquired war-built facilities. When in full operation, they will employ an estimated 41,000 workers.

Direct investment by foreign companies has been vigorously encouraged. Of some 1,075 new companies established in the Commonwealth since the end of the war, 989 have been of Australian origin, 52 from the United Kingdom, 32 from the United States, one from Canada, and one from India. The accompanying table indicates the distribution of new enterprises among the various industrial categories.

DISTRIBUTION OF NEW AUSTRALIAN INDUSTRIES BY GROUPS

Industrial Groups	*New Projects since mid-1945*	*Total No of Establishments 1944-45*
Treatment of Mine and Quarry Products	34	458
Bricks, Pottery, Glass, etc	28	318
Chemicals, Dyes, Paints, etc	110	862
Industrial Metals, Machines, etc	168	8,173
Precious Metals, Jewelry	10	267
Textiles and Textile Products	72	865
Skins and Leather	33	581
Clothing	83	4,773
Food, Drink, Tobacco	92	5,664
Woodworking and Basketware	25	2,873
Furniture, Bedding, Etc	21	959
Paper, Printing, Bookbinding	32	1,688
Rubber	16	286
Musical Instruments	1	37
Miscellaneous Products	41	650
Heat, Light and Power	9	476
Total	1,075	28,930

Along with this infusion of new enterprise, a significant but minor part of it backed by foreign capital, has come a steady increase in imports of new capital equipment. A special interdepartmental committee set up by the Government passes upon import permits for essential machines and tools.

By the end of 1946, factory employment in Australia was the highest on record, totaling 777,000 workers. Employment in the Commonwealth at that time reached 2,161,000. In 1938-39 the number of factory workers was 542,200 and in 1943-44, at the war peak, 744,500.

Increasing employment and production have been paralleled by a substantial rise in power consumption and extension of power facilities. In 1938-39 consumption amounted to 4,688,000,000 kwh. This rose to 6,817,000,000 kwh in 1944-45.

Continued operation of several wartime manufacturing activities has strengthened the Australian industrial structure. Aircraft, motor vehicles, and electronic products are now being produced. The government has undertaken a shipbuilding program under the direction of the Australian Shipbuilding Board. New industrial operations will include plastics, optical glass, surgical instruments and rayon manufacture. Australia now produces more than 100 chemical products not previously processed in the country. Machine tool production is more self-sufficient than before the war.

Australia's iron and steel industry now has 6 blast and 21 open-hearth furnaces which produce 1,500,000 tons of iron and steel products from local ores. Seven shipyards are now engaged in major repairs and ship construction. Wool consumption of Australian textile mills has been about 10 per cent of national production and an increase is expected.

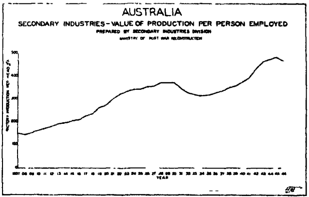
Development of hydro resources is being undertaken. The Commonwealth Bureau of Mineral Resources is surveying possible extension of the mining industry. The Commonwealth Aluminium Production Commission has been set up to investigate the utilization of bauxite deposits in Tasmania. Four state governments are promoting the exploitation of existing black and brown coal areas. Legislation in all states places post-war development projects under state commissions and regional boards to assure wider distribution of electricity.

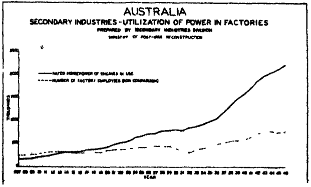
With a local market of 7,500,000 consumers, Australian industrialists are seeking a larger share of foreign markets to absorb expanding production. In the last decade, Australia's exports have been steadily rising and the share of manufacturers in export trade has advanced even more rapidly.

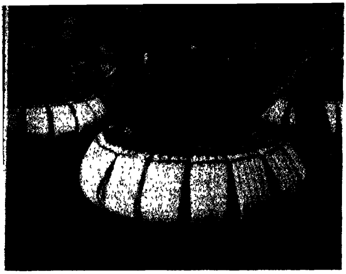
(In millions U. S. cy.)

	Total Value of Australian Exports	*Value of Manufactured Exports*
1934-35	363.2	19.4
1938-39	449.6	27.5
1939-40	545.3	43.8
1943-44	469.4	101.4
1944-45	497.0	90.2
1945-46	711.6	101.2

Australia's metallurgical and metalworking industries have modern equipment. During the war these industrial fields expanded rapidly to supply certain maintenance requirements of the army and navy. Today they are engaged in peacetime heavy manufacture.

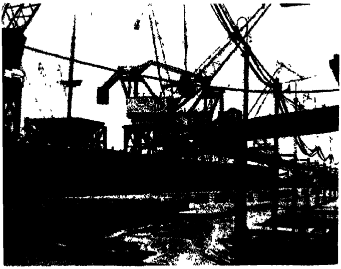




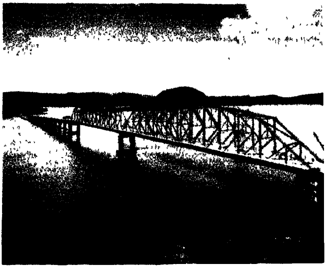


First stages in processing of fine marino wool tops for the drawing process of the Bradford system.

Australia's dairy industry is well organized and modern. Sanitary and efficient production characterize products for export.



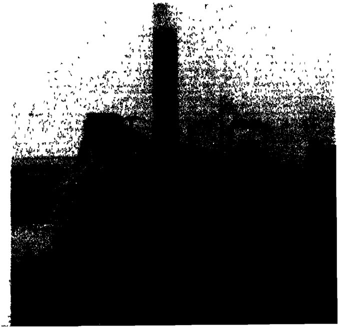
Lead stacks awaiting shipment at Port Pirie Smelters. Modern handling equipment facilitates loading of metals.



This steel bridge is a product of Australian factories. Welding was substituted for riveting in all members of truss spans.

Welded speed ring for turbine is packed by U. S. company for shipment to the Maraetai Public Works Plant, New Zealand.

General view of coke ovens and metal foundry of the Broken Hill Pty Co Ltd. Iron and Steel Works at Newcastle.



AUSTRALIAN STATISTICS
(1944-1945 data unless otherwise indicated)

Industrial employment	750,579
Industrial establishments	28,930
Salaries and wages *Excludes working proprietors*	$664,483,200
Average Annual Income in Industry *Excludes working proprietors*	$852.64
Total Capital Invested in Industry	$1,172,700,400
Iron and Steel Production (tons)	
Pig Iron	957,422
Steel ingots	1,356,913
Railroads (miles)	27,213
Highways (miles)	46,000
Kwh generated	6 817 442 000
Telephones (1947)	916,000

DATA ON SELECTED INDUSTRIES
(1945-1946)

Principal Manufactures	*No. of Establishments*	*No Employed*	*Value of Production*
Chemicals, dyes, etc	862	36,340	75.2
Treatment of non-metallic mine and quarry products	458	7,933	14.8
Food, drink, tobacco	5,664	105,194	200.0
Industrial metals, etc	8,173	319,314	472.2
Heat, light, power	476	9,453	44.8
Paper, stationery, etc	1,688	36,726	62.7
Textiles, etc	865	57,204	71.4
Other	10,744	178,415	217.6

The industrial growth of Australia, particularly during the last decade, has provided a better balance to the country's economic structure Pre-war export prices for primary surpluses carried a disproportionate burden in insuring the country's economic welfare New industries create new avenues of employment and a more stable home market Australia's price structure, involving rigorous controls during the war, has been continued into the transition period This has had a stabilizing effect upon the national economy and will benefit manufacturers by arresting inflationary prices for raw materials during the period of worldwide shortages Australia is also concerned with costs insofar as its export trade is concerned. It is emphasizing efficiency in industrial management and increasing productivity per man- and machine-hour It is also seeking stable long-term markets for its manufactured goods

RECENT INDUSTRIAL DEVELOPMENTS IN AUSTRALIA

Company & Products	*Foreign Interest*	*Remarks*
CHEMICALS		
I C I Australia, New Zealand, Ltd Will make urea-formaldehyde molding powders, and polyvinyl chloride*	U K	Building new plant at Botany, N S W
I C I Alkali (Aust) Pty Ltd, Osborne, S A	U K	Duplicating its facilities at a cost of $3,230,000
Noble (Aust) Pty Ltd, Melbourne	U K	$960,000 expansion
Monsanto (Aust) Pty Ltd, Braybrook, Vic Will double output of phenolic molding powders, increase sulpha drug output	U S.	Increased capital by $865,000
Nicholas Pty Ltd, Melbourne, pharmaceuticals		New plant, East Malvern, $640,000
Tantalite Ltd, Adelaide, will form New Metals (Aust) Ltd, to make tantalum, niobium, beryllium, caesium		$640,000 expansion
Amalgamated Metallurgical Corp, Ltd., Finsbury, S A, tantalum and niobium by new process Plans eventually to produce zirconium, hafnium and titanium		
Broken Hill Associated Smelters Pty Ltd, Port Pirie, S A, sulphuric acid from lead concretes* also copper sulphate	U K	
Robert Corbett Pty Ltd., Sydney, N S W, synthetic butanol, organic solvents		$3,230,000 new plant
Colonial Sugar Refining Co Ltd, Sydney, cellulose acetate* and acetic anhydride		$3,230,000 new plant
Australian Commonwealth Carbide Co Ltd, Electrona, Tasmania, carbon black		Resumption of production through agreement with Canadian owner of formula
Euston Lead (Aust) Ltd., Melbourne, white lead under U S. patents		$182,400 new plant
Shell Co. of Aust Ltd., Melbourne, road bitumen and high-grade lubricating oil		Expansion
Shell (Queensland) Development Pty Ltd, Brisbane, Q, exploration		$2,400,000 explorations
Bitumen & Oil Refineries (Aust.) Ltd., Bunnerong, N.S.W., bitumen refinery*	U.S.	New $3,230,000 plant
Vacuum Oil Co. Ltd., Melbourne, building a new-type refinery near Altona, Victoria.		Refinery, $2,400,000

* Indicates new product not previously made in Australia)

Adelaide Chemical Co Pty Ltd, bleached barites, barium sulphate, barium carbonate		New plant
Synthetic ammonia plants at Ballarat and Albion, Vic, and Villawood and Mulwala, N S W, were government-built and are all being extended for ammonium sulphate, three will produce methanol		Expansion

INDUSTRIAL METALS, MACHINES, Etc.

Broken Hill Pty Co Ltd, has taken over Australian Iron & Steel Co Ltd, iron and steel products, rails*, hot-cold strip*		$25,600,000 expansion
Zinc Corp Ltd, Broken Hill, N S W, smelting, refining and manufacture of non ferrous metals	U K	Expansion
Mt Isa Mines Ltd, Mt Isa, Q, lead, silver, copper, mining and smelting	U S -U K	Expansion
Australian Government Aluminum Production Commission, Launceston, Tas, aluminum*		New industry
West Australia State Government, Wundowie, W A, charcoal iron*		New industry
Electronic Industries, Ltd, Melbourne, electronic equipment, dry batteries		New plant in production
British Oil Engines, Australasia, Pty Ltd, Waterlook, N S W, gasoline, kerosene, and oil engines	U K	New plant
Lister Blackstone Pty Ltd, St Peters, N S W, gasoline and diesel engines	U K	New plant
Perkins (Aust) Pty Ltd, Lidcombe, N S W, diesel engines	U K Lic	New plant
Commonwealth Aircraft Corp, Port Melbourne and Lidcombe, N S W, gas engines and aircraft*		New plant
B O Morris (Aust) Pty Ltd, St Marys, N S W, flexible steel shafting*, grinding wheels and files	U K	New plant
Wiltshire File Co Pty Ltd, Tottenham, Vic, stainless steel knives*	U S	New plant
Tubemakers of Australia Ltd, Adelaide, S A, Clifton Hill, Vic, St Leonards, N S W, seamless tubes, conduits	U K	New plant
British United Shoe Machinery Co of Aust Pty Ltd, Mitcham, Vic, shoe machinery	U K	Expansion and new plant
Pope Industries Ltd, Kilkenny, S A, hand tools		Expansion
Commonwealth Government Small Arms Factory, Lithgow, N S W, saws, tools*, sewing machines*		New products
Miller Cycline Forging Pty Ltd, Abbotsford, Vic, tools and knives*		New plant
Commonwealth Government, Echuca, Vic, ballbearings		War plant continuing production
Commonwealth Engineering Co. Ltd, Granville, N S.W, complete buses*, diesel engines		Projected
Tayclox Precision Engineering Co Pty Ltd, South Melbourne, chiming spring clocks		Expansion
Westclox (Aust) Pty Ltd, Auburn, Vic, spring clocks and watches*	U S	New factory
M B Johns Ltd, Ballarat, Vic, steam valves		Expansion
Philips Electrical Industries of Aust, Pty Ltd, Finsbury, S A, electrical and radio equipment	Holland	Expansion
Metal Mfrs Ltd, and *Standard Telephone & Cables Ltd*, Maribyrnong	U K	New factory, not yet in production
Olympic Cables Ltd, Footscray, Vic		New plant in production
Cable Makers of Australia Ltd, Liverpool, N S W		New factory and plant in production
Pyrox Ltd, Carlton, Vic, electrical products*, diesel injection equipment, sound and projector equipment, Bosch patents		New factory and plant in production
R. & C Thomas Bros Pty Ltd, Tottenham, Vic, electric motors	Sweden	New factory and plant being built
Servex Industries Ltd, South Melbourne, electrical appliances		New plant
Joseph Lucas (Aust) Pty Ltd, Carlton, Vic, electrical equipment		Expansion
J S. Ryding, Sandringham, Vic, electric clocks*		Expansion
Tink Mfg Co. Pty Ltd, South Melbourne, electric clocks*		New plant
Meridian (Aust) Pty Ltd, Melbourne, electric clocks*		In production
Synchronome Electric Co (Aust) Pty Ltd, Brisbane, Q, industrial and domestic electrical clocks*		In production
Vactric Electric Appliances Ltd, Finsbury, S A., vacuum cleaners and electric motors	U K	New company
Electricity Meter & Allied Industries, Ltd., Waterloo, N S W, electrical equipment, telephones, air conditioners, cutlery, plastics		Expansion
Insulators Pty. Ltd., Auburn, Vic, aluminum oxide*, insulators		New factory being built
Overseas Corp. (Aust.) Pty Ltd, Melbourne, stoves, carpet sweepers	U K.	Some new facilities
Kelvinator (Aust) Pty. Ltd., Finsbury, S. A, new model refrigerators	U.S.	Expansion
Rootes Ltd., Port Melbourne, Vic, motor car and truck assembly, and parts manufacture	U.K.	New plant
Standard Cars Ltd., Melbourne, auto assembly	U.K.	New plant
General Motors-Holdens Ltd, Port Melbourne, Vic. and Woodville, S.A., cars and trucks	U.S.	New plant

(* Indicates new product not previously made in Australia)

Ford Motor Co of Australia Pty. Ltd, Geelong and Ballarata, Vic, cars and trucks	U S	New plant
Chamberlain Industries Ltd, Welshpool, S A, tractors		New plant, production in 1948
Kelly & Lewis Ltd, Derwent Park, Tas, Springvale and Footscray, Vic, tractors, laundry equipment		New plant
International Harvester Co Australasia Pty Ltd, Geelong, Vic, tractors, trucks and implements	U S	Proposed manufacture
Freighters Ltd, Moorabbin, Vic, trailers* and refrigerated vehicles		Expansion and new plant
Ansett Transport Industries Ltd, Essendon, Vic, bus bodies		New plant
Repco Ltd, Melbourne, Vic, and Launceston, Tas, car parts and accessories		New plant
A P.A C Industries Ltd, Finsbury, S A, car parts, accessories, and garage equipment		New plant
Rubery Owen & Kemsley (Aust) Ltd, Finsbury, S A, auto components		New plant
Malcolm Moore Ind Ltd, Port Melbourne, earth moving equipment, handling machinery	U K	New plant
Lawton, J A, & Sons Ltd, Adelaide, S A materials handling equipment		New plant
Tutt Bryant Pty Ltd, Rydalmere, N S W, earth moving equipment and material handling equipment		New plant
Ruston & Hornsby (Aust) Pty Ltd, Port Melbourne, Vic, earth moving equipment	U S -U K	New plant
Industrial Engineering Ltd, Braybrook, Vic, earth moving equipment	U S Lic	New plant
Wilcolator (Aust) Ltd, Melbourne, thermostatic controls*	U S	Expansion
Indo-Austral Engineering, Auburn, Vic, textile machinery	India	Projected
Mytton's Ltd, South Melbourne, Vic, stainless steel beer barrels*	U S Pats	New factory projected
Hard Metals Pty Ltd, Auburn, N S W, carbide tipped tools*	U S	New plant
Club Razor Blades Pty Ltd, Auburn, Vic razor blades*	U S	New factory
Australian Forge & Engineering Pty Ltd, Lidcombe N S W, carbide tipped tools*	U K	Expansion
Tilbrook, R P, Kensington, S A, motorcycles*		New plant, production in 1948
Everett Products Pty Ltd, Portland, Vic, hypodermic equipment*	U K	New plant in production
Standard Telephones & Cables Pty Ltd, Sydney, automatic exchange equipment, cables	U S	$6,400,000 plant projected

TEXTILES

Courtaulds, S, & Co (Aust) Pty Ltd, Tomago, N S W, rayon yarn*	U K	New industry to cost $16,000,000
Bruck Mills (Aust) Ltd, Wangaratta, Vic, rayon piece goods cord	Canada	New $3,230,000 plant in production
Burlington Mills (Aust) Ltd, Rutherford, N S W, rayon piece goods	U S	New $4,300,000 mill in production
Hollins Mills of Australia Pty Ltd, Villawood, N S W, woolen and cotton fabrics	U K	New $1,600,000 mill in production
Associated Cotton Textile Industries, Ltd, Woodville, S A, cotton goods	U K	New $3,230,000 plant in production
British Australian Carpet Mfg Co Ltd, Tottenham, Vic, wool carpets	U K	New plant
Westminster Carpets Pty, Ltd, Dandenong Vic, carpets of wool and rubber*		New factory
Woolcord Fabrics Ltd, Seymour, Vic, wool cord upholstery*		New factory
California Productions Ltd, Bathurst, N S W, clothing and footwear	U S	$1,600,000 capital

MISCELLANEOUS

Benger-Genatosan Pty Ltd, Sydney, food and medical products	U K.	$1,600,000 capital, new plant projected
Australia Paper Mfrs Ltd., paper products		Will spend $16,000,000 in four years on new mills and extensions
Australia Pulp and Paper Mills, Ltd, Burnie, Tas		$3,230,000 expansion by 1950
Australia Newsprint Mills Ltd, Boyer, Tas		$6,400,000 expansion
Tasmania Paper & Timber Mills Ltd.		$6,400,000 expansion
Firestone (Aust) Ltd., Finsbury, S A, rubber goods	U.S	$3,230,000 capital
Dunlop Rubber (Aust.) Ltd, tires	U K.	$6,400,000 expansion and transfer of plant
Goodyear Tire & Rubber Co. (Aust.) Ltd., Granville, N.S.W., tires, rayon cord	U.S.	Expansion

(* Indicates new product not previously made in Australia)

BELGIUM

Industrial reconstruction in Belgium has involved no major changes in the nature of the economy, although the government intends to exercise a closer supervision over business Its objectives are the nationalization and specialization of industrial production, notably in steel and textiles The assembly of imported parts in order to encourage export of such finished products as motor vehicles will be encouraged Considerable capital investment is being expended in the modernization of industry and the restoration of agriculture An effort to compensate for the loss of the German market is being made through a reorientation of foreign trade

During the occupation of Belgium, some 260,000 persons were deported to Germany and other parts of Europe The loss of life as a result of the war and occupation amounted to around 90,000, of which a high proportion were skilled workers In 1946 the population of Belgium was 8,345,000 or about 50,000 less than in 1939

Belgium suffered relatively little large-scale destruction of its manufacturing industries Except for the devastated areas of the Ardennes, Liege, and Antwerp, destruction mainly affected transportation, the invasion route for Europe. Belgium lost nearly 60 per cent of its merchant fleet At the time of liberation, the Rhine fleet was about 60 per cent of its pre-war size Railroads lost 47 per cent of their rolling stock and 59 per cent of their locomotives Of 927 bridges, 804 were destroyed or damaged

Industry chiefly suffered during the war from lack of maintenance and replacement Recovery after liberation was rapid despite shortages of manpower, fuel and raw materials Having been liberated in a week, Belgium became a major base for Allied armies. Although Belgium received lend-lease from the United States, the goods and services supplied to American forces heavily outbalanced Lend-Lease in value. Since Belgium also aided British and Canadian troops, repayment went far to expand the nation's foreign exchange reserves.

By the mid-1947. Belgium's index of industrial production had regained the level of 1938 and passed it in some manufacturing fields.

Prices in Belgium, as in most other countries of Europe, have soared in the post-war period. The general price index stood at 338 in July, 1947, based on 1936-38 = 100. Although there have been predictions that inflated prices would seriously hamper recovery of foreign markets, trade has continued to expand steadily. The volume of trade in the first half of 1947 was just below the 1936-38 level, and was about three times the pre-war value.

Although imports still exceed exports by a substantial margin, Belgium's problem of balancing payment is less serious than for most of its neighbors because of the hard currencies accumulated during the closing months of the war arising out of the sale of goods and services to the Allies.

Immediately upon liberation, British and American missions placed large orders with Belgian factories for tank treads, tires, textiles, and iron and steel products During the period between liberation and the end of the war, the United States provided Belgium with lend-lease valued at 114,000,000 dollars, Britain provided aid valued at 114,000,000 dollars; and Canada supplied another 22,800,000 dollars In return, reverse lend-lease and mutual aid totalled 433,000,000 dollars for a credit in hard currencies of 182,500,000 dollars

Advances to Allied soldiers billeted in Belgium and paid in local currencies totalled another 320,000,000 dollars, which has been almost entirely redeemed in foreign funds The United States and Canada granted 4,500,000 dollars in credits for Belgian reconstruction.

The government acquired 49,000,000 dollars worth of equipment from U S surplus military stocks in Europe and paid for it with a loan from the Office of the Foreign Liquidation Commissioner (U S) Argentina granted a 26,000,000 dollar credit, and Sweden (through a payments agreement) advanced a credit of 23,000,000 dollars

Exports in 1946 were valued at 677,000,000 dollars while imports amounted to 1,200,000,000 dollars, leaving a deficit of 523,000,000 dollars to be made up from foreign exchange holdings Estimates of 1947 indicated that the gap between the value of exports and imports would be reduced by more than 20 per cent to around 400,000,000 dollars

Coal is the basis of Belgian industry. The country possesses few other raw materials and very small hydroelectric reserves Industrial activity is keyed to the imports of raw or semi-finished goods The following table will give the approximate 1947 production of principal industries as based upon 100 as the average production before the war

1947 INDICES OF PRODUCTION

Cast iron	87
Crude Steel	88
Metal products	100
Cement	95
Synthetic ammonia	155
Sulphuric acid	83
Cotton textiles	145
Woolen	158
Rayon	140
Leather	75
Newsprint	100

BELGIUM STATISTICS

Employed in industry, 1946	1,500,000
Iron and Steel production, 1947. Estimate in metric tons of the Committee for European Economic Cooperation for Belgo-Luxembourg	4,600,000
Railroads (miles)	3,089
Highways (miles)	6,625
No of telephones, 1946	379,600
Kwh produced, 1946	6,243 million
Trade, 1946:	
Imports	$1,200 million
Exports	$677 million

BRAZIL

Brazil leads the other Latin American countries in the value of goods produced, in the number of manufacturing establishments, and in the number of those gainfully employed in industry. By reason of its resources, Brazil is in a favorable position to become the most industrialized of the Latin American republics.

Industry is largely located in the states of Sao Paulo and Rio de Janeiro. These two states account for over half of the factories in Brazil and represent the largest markets for all goods whether imported or manufactured locally. Approximately 85 per cent of the country is industrially unimportant, although there is a scattering of plants for sugar refining, alcohol manufacture and textiles in the northern and northwestern states. Brazil's industries may be reviewed for seven states which possess approximately 90 per cent of the country's hydroelectric power, operate over 85 per cent of its factories and consume over 90 per cent of its manufactured goods.

PRODUCTION BY STATES
(1940)

States	*No of Factories*	*Per cent of total*
Sao Paulo	28,329	40.6
Federal District	10,207	14.6
Minas Geraes	6,954	9.9
Rio Grande do Sul	6,341	9.1
Estado do Rio	3,069	4.4
Santa Catharina	3,000	4.3
Parana	2,300	3.3
Others	9,826	13.9
Total	70,026	100.0

In 1920 the census revealed that there were approximately 13,500 industrial plants in the country. By 1938 the number had more than doubled. According to recent reports in the local press, there are now about 85,000 factories in Brazil. For the most part, these plants are affected seriously by the absence of modern equipment and construction materials. Many are operated with obsolete machinery and are uneconomical, particularly from the viewpoint of the poorly paid workmen who have demonstrated that cheap labor is neither efficient nor inexpensive in a competitive market. During World War II, large quantities of machinery were shipped to Brazil for utilizing fully sources of supply both for the country itself and for export to the United States and Allied nations. Supplies of machine tools, processing plant equipment and machinery for the metallurgical industries shipped to Brazil over the last seven years have required a level of technological development beyond the country's resources in trained and skilled labor. It must not be overlooked that the country is still in a comparatively early stage of industrialization. In the most industrialized areas of the southern states, a large and uneducated population continues to depend on primitive agricultural occupations. Although the government is using every means to remedy the situation, a high majority of employees with only the scantiest of mechanical training are found in the factories, mines and construction fields.

Brazil has suffered from an inadequate supply of high-grade coal and oil. Beneficiation processes will probably make it possible to use native coal for coking in the National Steel Mill of Volta Redonda. Unceasing exploration for oil has been rewarded by the discovery of proved oil reserves in the Labato-Jones, Itaparieta, Aratu and Candeias fields. The oil deposits in the far west have never been fully determined, nor would such a supply have immediate access to the markets on the eastern seaboard.

The government's policy of restricting the investment and operation of foreign capital in Brazil has recently become a serious obstacle to the formation of large enterprises in the country. Much hesitancy has been manifested by foreign companies interested in establishing branch manufacturing plants in the Brazilian market. Furthermore, the present system of exchange control limits the disbursement of dividends outside the country. Legislative restrictions on specific Brazilian industries prohibit the initiation or expansion of enterprises involving foreign capital.

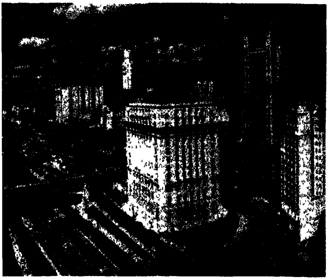
The outstanding industrial accomplishment in Brazil during recent years has been the creation of the National Steel Mill at Volta Redonda. Utilizing an Export-Import Bank loan and backed by a subscription of stock held both by the public and the government, Brazil has been able to finance and construct the largest steel plant in South America. The country's per capita consumption of iron and steel has been low as compared with other countries. The price has always remained high and considerable pre-war tonnage was imported from England, Belgium and Germany.

The National Steel Mill is located about 90 miles from Rio de Janeiro in the state of Minas Geraes. The plant is designed to manufacture coke, pig iron, blooms, billets, structural shapes, merchant steel, tin plate, sheets, rails, plates, reinforcing bars, etc. Coke will be manufactured in a battery of 55 ovens connected to a by-product plant. Provision was also made for 55 more ovens should conditions warrant their addition. Chemical by-products will be an important contribution of this phase of the steel industry.

Although the Brazilian steel industry was first established in Sao Paulo in 1556 when Mateus Nogueria produced several iron tools from local ores, little was done to exploit the tremendous mineral resources of the country until the last decade. The total production of pig iron in 1937 was only 98,000 tons, in 1946 the total production was 350,000 tons. Rolled iron products increased from 71,419 tons in 1937 to 180,000 tons in 1946.

Although the National Steel Mill is the most impressive development of the Brazilian metallurgical industry, many of the smaller industries have kept pace. In the fall of 1947 Mineracao do Brazil inaugurated a second blast furnace with a capacity of 3,000 tons of pig iron per month. Two more blast furnaces with a total capacity of 4,000 tons a month are also being constructed at their Jafet Steel Mills in Mogi das Cruzes, near Sao Paulo.

Brazil's strength for industrial development lies in the immediate availability of cheap and abundant power. Ranking fourth in hydroelectric resources, the country comes in order after the U S S.R , the United States and Canada With a potential of 10,000,000 kw, the country has an installed capacity of only 732,000 kw largely concentrated in the industrial State of Sao Paulo and the metropolitan area of Rio de Janeiro The total installed capacity from all types of plants is 1,232,686 kw from approximately 1400 electric plants The State of Sao Paulo, which is the industrial heart of Brazil, is characterized by a topographic oddity in that all streams rise within sight of the Atlantic Ocean, flowing westward and then south to form the large river systems of the Tiete, Paranapenama, Igassu, etc and finally joining the River Plata Through the engineering genius of an American engineer, several of these rivers have been dammed to form a network of lakes Water is dropped over the Serro do Mar escarpment with a head of 2,415 feet to the power stations located between Sao Paulo and the port of Santos Brazilian engineers also envision the utilization of the tremendous power of the Paulo Affonso Falls in the north If the power of this waterfall could be harnessed, together with a series of irrigation projects to assure a regular water supply, the Sao Francisco valley would become a new and highly productive agricultural area



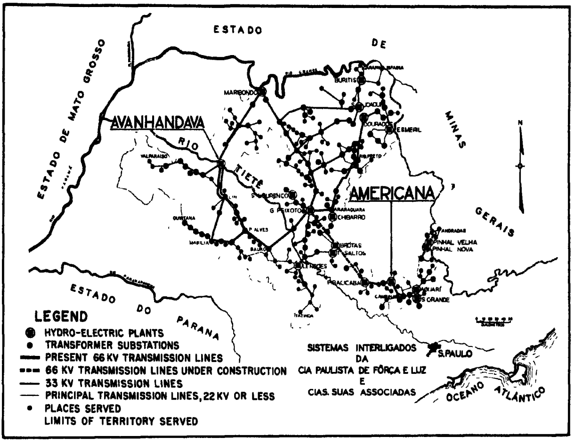
A general view of the heart of Sao Paulo, the world's fastest growing city and center of Brazilian industry.

Elevated view of blast furnace, trestle and ore yard of the Brazilian National Steel Company, Volta Redonda.

South America's most modern hydro-station opened August, 1947. Two generating units of 14,200 hp each will be connected with the system of Compambia Paulista de Forca e Luz.

Brazil's feverish quest for oil is illustrated by drilling activity in the Pitanga field, State of Bahia.

Under U. S. supervision new 20 million dollar plant of Companhia Nitro Quimica Brasileira will produce viscose rayon.



Map of the vast interconnected system of the Cia. Paulista de Forca e Luz with associated light and power companies. The Avanhandava plant, shown on top of facing page, is to be followed by the Americana plant now in the drafting board stage.

Cuba's, like Brazil's metal industry, has attained recognition by reason of its vast Nicaro Nickel plant shown above.

Founded in 1943, Companhia Brasileira de Material Ferroviario in Sao Paulo assembles and repairs freight cars. Having the backing of several Brazilian railroads, it hopes also to manufacture railroad equipment.

CANADA

Economic conditions in Canada in the first two years after the war have been characterized by the smoothness with which the transition from war to peace has been effected.

Domestic requirements for consumer goods have been high as a result of the deferred demand from the war period supported by liquid savings Current demand based on disposable personal income has continued to rise since the ending of hostilities

Large-scale reconversion, modernization, and expansion programs of private business have provided a strong demand for capital goods. Business concerns, as a whole, entered the post-war period in a strong and liquid financial position, while the financial markets have been reasonably favorable to them in providing funds for their investment programs The relief and rehabilitation needs of war-devastated countries have provided an additional demand for consumers' and producers' goods and have been made effective, in part, by large loans granted to these countries by the Dominion Government in the first post-war years By the middle of 1947, Canadian dollar loans to war-devastated countries (including the United Kingdom) amounted to 1,857,000,000 dollars Credits to the United Kingdom (apart from wartime aid and a gift of 1 billion dollars) amounted to 1,250,000,000 dollars

The re-directing of human and physical resources to meet the peace-time demand for goods and services has been carried through without serious dislocations War workers and war veterans were absorbed into the civilian working force with a volume of unemployment that at no time exceeded 6 per cent of the working force and which averaged between 2 and 3 per cent in 1947 The reconversion of plant and equipment to peacetime use was practically completed by mid-1947. During the transition period, as a result of substantially increased demand, shortages of building materials and equipment were felt in spite of continuously rising output in a number of industries. Domestic shortages of certain basic materials—of which iron, steel, lumber, copper, lead, zinc, and nickel are most important—have slowed down the expanded rate of production in a wide range of consumers' and producers' goods The tight labor market situation, to a lesser degree, has also been a factor limiting production Although shortages are a continuing problem, the physical volume of production has been rising since the last quarter of 1946

The Canadian system of price controls held the price level to a moderate increase from 1940 to 1946. With the extensive relaxation of these controls in 1946 and 1947, the price level has been rising steadily. The general wholesale price index was 40 per cent above 1939 at V-J Day, most of the increase having occurred before controls were imposed in 1941 By mid-1947 the index was 70 per cent above the 1939 level

An outstanding feature of private investment in Canada since the end of the war has been the proportion of funds going into the conversion, modernization and expansion of existing plants and the building and equipping of new facilities Much of this effort is directed toward stimulating production in industrial fields where Canada is already an important producer, such as in the processing of wood and paper products, food products, and non-ferrous metals Closely related to this type of investment is an attempted integration of production processes In some cases the facilities are used to process materials or supplies needed for main commodities, in others to use waste material resulting from production In many instances, new production units are being established to increase the variety of products Thus more than 200 commodities now being produced in Canada were imported before the war These include various types of heavy and light machinery, industrial equipment, new textiles, wood and paper products, and chemical and allied products A number of plants, particularly in the chemicals field, have been built to produce commodities by recently developed processes The result of these post-war developments has been an increased capacity to meet domestic and foreign demands for Canadian products.

Spillway at Isle Maligne power station sends 540,000 hp to war-developed aluminum plant near Arvida, Quebec.

Portion of 130 acre Polymer plant engaged in the production of synthetic rubber and plastic resins.

To facilitate the integration and expansion of Canadian industrial production, the Department of Reconstruction & Development inaugurated a system of double-depreciation for approved projects. Under this regulation more than 200 million dollars in new industrial capacity approved by the government may be amortized at twice the normal rate.

Total foreign investment in Canada was estimated in 1945 at 7.1 billion dollars or about 200 million more than in 1939. Approximately 5.4 billion dollars of the 1945 foreign investment was of an industrial and commercial nature. The United States' share was 3.5 billion dollars. The United Kingdom held 1.6 billion dollars and other countries 300 million dollars. About 3.1 billions of the foreign funds invested in Canadian industry were in companies controlled outside Canada. British investment decreased, while American and other foreign investments increased during the war years. It has been a traditional policy of the Canadian government to encourage foreign participation in the development of Canadian resources. However, since 1934 the country has been a consistent net exporter of capital, although its international investment position is still that of a debtor nation.

Since the end of the war American firms have greatly expanded their Canadian facilities, using in part more than 200 million dollars of accumulated profits. By 1947 the following new developments had been reported. Kalamazoo Vegetable Parchment Co. will produce sulphate at Espanola, Ont., where a 10 million dollar investment has been made. Marathon Paper Co. acquired timber rights and will build a 15 million dollar plant, Sorg Paper Co. is planning a 1.5 million dollar mill, St Regis Paper Co. is building a new paper-bag plant in Vancouver, Kimberley-Clark Corp. will put more than 15 million dollars in a sulphate mill, expansion of the Studebaker, Packard, Nash, Ford, and Chrysler facilities is under way, and Kaiser-Frazer has entered the Canadian market, Fruehauf and Trailmobile, manufacturers of trailers, will begin production in Canada, International Harvester is building a new plant at Chatham, Ont., and Reo Motor Co. has a new plant at Leaside.

In the field of industrial supply, the following companies are expanding or building facilities in Canada: Perfex Corp., Penn Electric Switch Co., Ahlberg Bearing Co., Continental Can Co., Moore Business Forms, Inc., Niagara Garnet Corp., American Can Co., Eagle-Picher Co., Canadian General Electric Co., Ltd., General Aniline & Film Corp., Ray-O-Vac Co., Monsanto (Canada) Ltd., Construction Machinery Co., Eddington Canning Co., Reynolds International Pen Co., Hannifin Mfg. Co., Minneapolis-Honeywell Regulator Co., Union Carbide & Carbon Co., Canadian Johns-Manville Co., Ltd., American Brake Shoe Co., Merrimac Hat Corp., and McNally Pittsburg Mfg. Corp.

Because many of the larger Canadian business firms are branches of United States firms, or are closely associated with them, there has been a tendency for Canadian industrial research laboratories to concentrate on analysis and testing and do only a limited amount of field development work. They depend upon their American affiliates for major research developments. Most pure research is conducted in universities and by the National Research Council, a federal agency. Other government departments engage primarily in applied research aimed at developing natural resources. During the war, however, some industrial laboratories undertook more fundamental studies. Canada's research facilities and personnel have been expanded considerably in the last five years. Government expenditure on scientific activity increased nearly five-fold between 1939 and 1946. This represented a tripling of non-military research expenditure and a 1700 per cent increase in funds for military research.

Examples of important research in the war period are the development of processes for extracting starch from wheat, and of magnesium from dolomite and brucite. Canada further perfected its synthetic rubber processes, and worked in the field of atomic energy.

The economic outlook for industry in 1948 and for several years to come is contingent upon developments in Canada's foreign trade. Its economy is geared to a high level of exports and imports. A falling off of exports or inability to obtain sufficient quantities of basic imports like coal, oil, and metal products can materially lower the level of economic activity.

Canadian made electric air-blast circuit breaker installed at Three Rivers substation of Shawinigan Water and Power Co.

With the world's highest per capita consumption of oil, Canada produces only 15 per cent of its demands. View is of a scrubbing plant in newly developed fields in Alberta.

Some latitude now exists for neutralizing a decreased demand for exports to one foreign market by redirecting commodities to other markets During and immediately following the war the Canadian government vastly expanded its commercial representation at foreign embassies and legations Efforts are being directed toward discovering Canadian markets for foreign products to assure the ability-to-pay on the part of foreign consumers

The over-all export position, however, will depend on whether American aid to Europe is forthcoming on a liberal scale during 1948 and the following years as envisioned by the Marshall Plan This aid will increase the ability of European nations to buy Canadian exports, and will also place Canada in a better position from the viewpoint of foreign exchange to extend continued aid to war-devastated countries Foreign exchange affects Canada's ability to import Traditionally the country has sent a large portion of its exports to the United Kingdom and has received a large part of its imports from the United States With the pound sterling not freely convertible into American dollars, Canada has had to pay for its imports from the United States out of a reserve of gold and American dollars built up in the war years. At the present rate of withdrawal, this reserve will be exhausted in 1948 Accordingly, Canada is likely to face a continuing problem of financing its imports. Improvement of the situation will depend on the expansion of multilateral trade, greater convertibility of the pound sterling, and perhaps some adjustment in the structure of the country's industry For the immediate future, any American aid to Western Europe in 1948 will tend to make the problem more manageable by enabling these countries to pay at least in part for deliveries from Canada and the Latin American countries in hard currency.

In most respects, the Canadian economy is in a healthy condition The principal effect of the war was to accelerate structural changes already developing within industry before the war. The period of transition to a peacetime basis has, therefore, been more a consolidation of gains from the war period than a liquidation of war developments without survival value.

A segment of the Canadian economy particularly stimulated during the war were the export industries. Canada's principal exports are food, wood, and nonferrous products of a raw or semi-processed nature Apart from certain food products of animal origin, most of the commodities now being exported in volume were exported on a large scale before the war and Canada can continue to market these on a competitive basis. The potential demand for Canada's principal exports is very large, particularly as they constitute basic supplies for the relief and rehabilitation of devastated countries. No difficulty will be encountered in disposing of these exports over the next few years if the world's current foreign exchange difficulties can be alleviated.

The most important expansion of Canadian manufacturing industries was in metalworking and the chemical and its allied fields. Production and employment in both have dropped from wartime highs, but the reduction largely represents the liquidation of war material production, such as ships, aircraft, fighting vehicles, guns, and munitions. In most other directions, employment and production in metal and chemical products plants have increased Wartime expansion of primary iron and steel has been consolidated with a larger and more varied production The secondary iron and steel industries are also producing or will soon be producing more and greater variety of consumers' goods than before the war, including many items not previously made in Canada or only produced on a limited scale A similar situation exists in the other metal-working industries, chemicals, and industries which expanded less spectacularly.

During the war period, Canada's investment in durable physical assets of a strictly productive nature was estimated at about 4 5 billion dollars. About 3 5 billion was for use directly or indirectly in prosecuting the war Of this, 1 7 billion was for plant and equipment to make munitions It is believed that about two-thirds of the 3.5 billion dollars outlay will be usable for peacetime purposes Approximately 2 billion dollars more has already been expended in the two post-war years in acquiring durable physical assets of an industrial nature, with one third directed toward manufacturing industries and some what less than one-third to utility industries.

In the eight years that have elapsed since the start of the war there has been a notable increase in Canada's industrial potential In many respects the increase has been greater than investment outlays would indicate Before the war, Canadian manufacture was concentrated on the primary processing of goods for export and the final processing of consumer goods for domestic consumption A goodly share of wartime investment represented the acquisition of production facilities in the intermediate sphere of processing As a result, Canadian manufacturing industries as a whole, through a better integration of facilities, have acquired greater flexibility for undertaking alternate types of production, a development already evidenced by marked increase in the variety of goods being produced.

Accompanying the wartime and post-war expansion of production facilities, there has been a material change in the composition of the working force industrially, occupationally, and geographically. Against an increase in the adult population of around 9 per cent between 1939 and 1946, the gainfully employed population increased about 15 per cent and the employed population close to 25 per cent As employment in agriculture decreased slightly, the increase in the employed population accrued entirely to the non-agricultural industries, and mostly to manufacturing industries which employed a working force 75 per cent larger than before the war and nearly as large as agriculture.

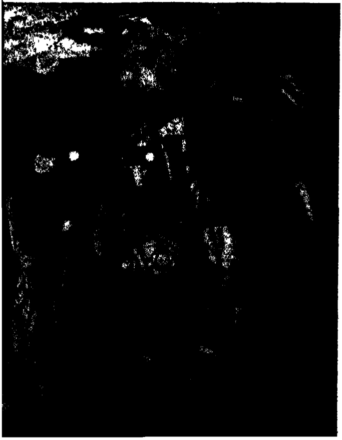
Occupational changes resulting from the industrial redistribution of workers materially increased the skilled work forces, while the accompanying population shifts promoted urbanization and augmented the working forces of Ontario and British Columbia at the expense of the Maritime Provinces and the prairie regions. These changes were an acceleration of trends that prevailed before the war and are not expected to alter in the near future.

An important feature of the developments of the last

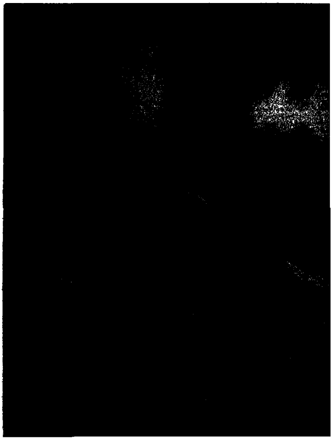
Final beating in huge vats prior to going on paper presses: Canada ranks third in the world as a producer of paper and wood products from its million sq miles of timber land.

Flow box in British Columbia's Powell River Company, Ltd. Worth 37 million dollars, the plant is one of the world's three greatest makers of newsprint with a yearly output of over 20,000 tons.

Operating on a 24 hour basis the Noranda Mines Ltd of the Kirkland Lake area processes 6,000 tons of ore daily. Here diamond drillers employ modern equipment and work in comparative safety.



Loading 2 of the largest blast furnaces in the British Empire. Over the war years Canada has doubled its production of pig iron and steel. Canada now has 137 steel furnaces, 83 of them electric.



DATA ON SELECTED LIST OF CANADIAN INDUSTRIES
1945

Industry	*No of Establishments*	*Number Employed*	*Gross Value of Prod*	*Value of Imports*[1]	*Value of Exports*[1]
				(in U S cy)	
Chemical and allied industries	973	60,723	478,532,689	79,758,655	111,318,110
Cement mills and rock products industries (non-metallic mineral prods)	789	32,525	405,736,477	265,405,010	59,555,035
Food processing industries (vegetable and animal products)	10,332	233,578	2,464,915,882	282,183,425	1,217,508,567
Metallurgical and metal working industries (iron and non-ferrous metals and their products)	2,871	410,069	2,754,694,983	483,579,431	907,635,748
Electric power generation[2]	625	20,000	283,379,000	100,000	13,000,000
Pulp and paper industry	109	39,996	398,804,515	7,682,837	300,709,413
(Other wood and paper industries)	10,544	159,377	785,846,205	42,077,879	187,331,129
Textiles and textile products	2,740	158,148	807,722,241	196,761,222	56,881,105
Others	692	24,956	154,115,874	228,326,683	377,391,246
Totals	29,675	1,139,372	8,533,747,861	1,585,875,142	3,231,330,353

[1] *Export and import figures shown are values of commodities of type and* NOT *values of products exported or imported by manufacturing industries shown. The 1946 imports amounted to $1.9 billion and exports to $2.3 billion.*

[2] *Estimates based on 1944 data*

eight years that has an important bearing on the future stability of the country has been a widespread improvement in the financial stability of industry. Most businesses were able to introduce greater flexibility into their financial structure by reducing the ratio of fixed charges and particularly by reducing debt or offsetting it with liquid reserves. This is especially significant since it also pertains to the farming communities, which were impoverished and badly in debt before the war. The accumulation of reserves has enabled many firms to finance post-war expansion with their own funds.

During the war, provincial and municipal governments were also able to improve their financial status from increased revenue, coupled with reduced services made necessary by conservation of manpower and materials. These governments, having limited powers of taxation, had encountered difficulties during the depression years because of relief expenditures. Offsetting the improvement on the provincial and municipal level has been a great increase in federal debt over the war years. This does not present as intractable a financial problem as do increases in municipal and provincial debt, since the federal government has wide powers of taxation and is responsible for the monetary and credit policy of the country. Once federal expenditures return to a peacetime basis, expenditures by all three levels of government should not represent a larger share of gross national expenditure than before the war so long as a high level of employment and income continues in Canada.

Prices and costs had been rising rapidly in 1946 and 1947, and the upward pressure continued into 1948. While the general wholesale price index was 40 per cent above the 1939 level at V-J Day, and 70 per cent above mid-1947, the cost-of-living index had risen 20 per cent and 35 per cent at comparable dates. Three factors are primarily responsible: (a) increased costs of imports from the United States following the dropping of price control there in 1946; (b) discontinuance of subsidies paid during the war and immediate post-war period to maintain the price level of key commodities; and (c) inflationary pressures built up during the war years while prices and wages were controlled. These forces have gathered momentum as controls have been eased or dropped. At the end of 1947 there was very little indication of a levelling off in prices. However, there still exists a considerable margin for increases before prices approach the world

PRINCIPAL MANUFACTURES AND VALUE OF PRODUCTION
(In Millions of $)

Slaughtering and meat packing	$505
Pulp and paper	399
Non-ferrous metals (smelting, refining)	356
Aircraft	379
Sawmills	231
Electrical apparatus and supplies	231
Automobiles	229
Flour and feed mills	224

CANADIAN EMPLOYMENT
1946

Agriculture	1,185,000
Mining	70,000
Forestry, fishing, trapping	115,000
Total Primary Industries	1,370,000
Manufacturing	1,240,000
Transportation, Communications	345,000
Construction	225,000
Trade, finance, insurance	695,000
Services	780,000
Total Secondary Industries	3,285,000
Unemployed	145,000
Total Working Force	4,800,000

level. The inflationary pressures, while strong, have not disrupted Canada's economy. The degree to which they will continue to affect the economy will depend largely on prices in the United States and on Canada's ability to continue purchasing abroad the commodities required to supplement domestic production.

The one really serious problem facing the Canadian economy is the balance of international payments. The situation deteriorated following the end of the war in three respects. In the first place, the value of imports in 1947 was about 3.5 times the 1939 level compared with a three-fold increase for exports. Secondly, and more serious, about four-fifths of the imports are coming from the United States, and must be paid for in hard currency, as against two-thirds before the war. Thirdly, the volume of exports to the United States is now one-quarter of total exports as against more than one-third before the war. Relatively, Canada now obtains less foreign exchange on current account than before the war to pay for imports from the United States. Since only a part of what is obtained is convertible into American dollars, the difference must be made up through American funds left in Canada by tourists, drawing on reserves of gold and American currency built up during the war and a few minor sources. An idea of the unbalance in trade may be gleaned from the following: commodity imports from the United States exceeded exports to that country by 735 million dollars in the first nine months of 1947.

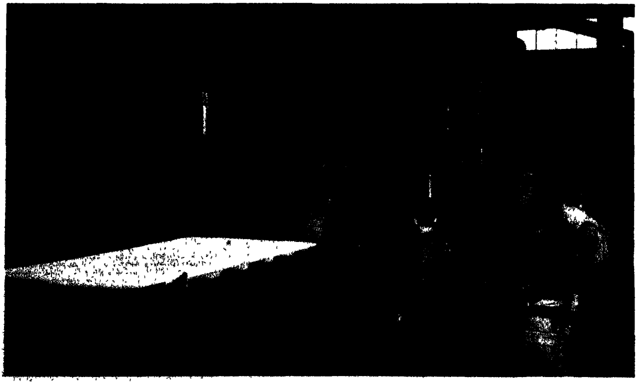
At the present rate of withdrawal, the Canadian reserve of gold and American currency will probably be exhausted sometime in 1948. A number of courses are open to the Canadian government to meet the situation, but the procedure adopted will depend to a large extent on the steps taken by the United States government to extend aid to Europe. Even under the most favorable circumstances, problems of foreign exchange will continue to beset the Canadian economy as long as international currencies are not freely available.

Toward the end of 1947, Ottawa reimposed some minor price controls to curb inflationary price trends, and tightened the regulations governing the use of United States dollars and the purchase of United States products.

GENERAL INDUSTRIAL DATA

No of Industrial Establishments, *manufacturing only*, 1946	30,000
Average Annual Income of Industrial Workmen, *manufacturing*, 1945	$1,650
Total Capital Invested in All Industry, *manufacturing only*	
1943	$6,300,000,000
1946 Estimated between	$6,500,000,000 and $7,000,000,000
Iron and Steel Production (tons), 1946	
pig iron	1,405,000
steel ingots and castings	2,335,000
Total	3,740,000
Miles of railroad	42,000
Miles of highways (paved and surfaced)	130,000
Total Kwh produced, 1946	41,603,708,000
No of Telephones, 1946	1,848,000

Largest of the iron and steel companies is Steel Company of Canada with 1,100,000 net tons of ingots annually. Its rolling mill produces large variety of bars, rods, sheets, plates and light structural shapes.



CHINA

Two years after the defeat of Japan war continued in China between the forces of the Central Government and the Communists in the northwestern provinces Economic conditions in China have been chaotic, despite desperate efforts to exert control over prices, production, and transport

At the present time China lacks the administrative organization, financial resources, and coordinated plans for orderly recovery Every effort is being exerted to prevent complete disintegration of what remains of the country's economic structure Vast foreign financial assistance will be required to put China into a condition from whence it can begin the exploitation and development of its full resources And such aid has been, and will be, conditioned upon some political settlement without which financial aid would be futile and wasted

The last fifteen years, during which China has had no peace, have left tragic marks upon the country's economic resources and population. Runaway inflation, business and administrative corruption, stagnation of industry, backward and disorganized agriculture, and completely disrupted transportation facilities have plagued the country The concerted effort of the entire people, the government, and the leading foreign powers will be required to rescue China from its present predicament *The most urgent need is for peace*

Since the end of the war considerable aid has been provided China through UNRRA, and by credits made available by the United States and Canada The Export-Import Bank made a loan of 83 million dollars A Surplus Property credit of 70 million dollars has been granted The lend-lease settlement with China provided 59 million dollars The Canadian government supplied 73 million dollars

A basic problem in China is transport. About 17 per cent of the rail lines and as much as 50 per cent of the locomotives and rolling stock were wrecked or are awaiting repairs UNRRA has delivered several hundred locomotives, several thousand freight cars, and tons of rails and ties for repair of trackage. In 1945 China had only 744 miles of railroads actually in operation

Before the war more than a million tons of shipping were engaged in the China trade, of which China owned 703,000 tons in 1936. Of this shipping service, 577,000 tons was lost during the war In addition, China lost 7,450 junks and 30,000 fishing boats. At the end of the war only 42,000 tons of shipping was in service. From the United States and Britain some 200,000 tons of small vessels (only a few of them over 5,000 tons) had been placed in service. The United States agreed to provide another 800,000 tons to help build up the merchant marine to an anticipated 1,500,000 tons estimated to be adequate to meet the demands for the time being.

Of a total length of highways measuring about 65,000 miles, nearly 70 per cent was partially or completely destroyed by military action. The loss of motor vehicles has been estimated at 50,000. The United States and UNRRA have replaced more than half this number and UNRRA's program included 62,000 tons of road building equipment In 1937 China had 24,980 miles of surfaced roads with a total of 72,080 miles of roads of all description.

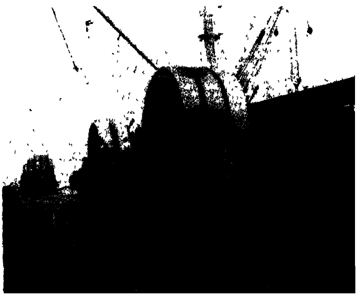
In 1946 China had an adverse balance of trade amounting to about 500 million U.S dollars and was importing about 4 times the amount of its exports These figures cover only commercial trade, excluding UNRRA deliveries The distribution of China's imports in 1946 among principal categories of supply was as follows 70 per cent raw materials, 24 per cent daily necessities, 5 3 per cent machinery and equipment, and 0 7 per cent coal, fuel, pitch, and tar Chaotic conditions in China have prevented a recovery of even traditionally important commodities, e g, the 1946 export of tung oil was estimated at only 30 per cent of the pre-war figure The government of China estimated the 1947 deficit in trade at 380 million U S dollars.

In China prices had risen by the end of 1946 to 6,000 times the pre-war level This has reduced the real income of fixed-salary employees to a fraction of pre-war, with consequent loss in efficiency The shortage of goods, and consequent speculation based on scarcities and rising prices, has reduced industrial activity to an exceedingly low point Exact statistics are either unavailable or unreliable

China faces the serious problem of bringing its international payments and receipts into reasonable equilibrium while food resources, external assets, and ex-enemy property are still available as buffers The basic problem is in part one of international economic relations There is a desperate need for imports while exports cannot be supplied There is also the question of internal finance, the lack of balance in the budget But overriding these difficulties is the need for a reduction in military expenditures occasioned by the continuing civil war, and for a strengthening and improving of administrative organization.

During the war China's industrial facilities were sharply expanded, despite the enemy occupation of a

These rotary kiln shells represent small part of 57-freight car train of machinery recently shipped to China from U. S. to construct Hwa Hsin Cement Plant near Hankow.



vast part of the country. A new industrial base was created in Szechwan, where 339 new plants were erected (many of them having been removed from the coastal area). Most of these industries were war plants but their facilities are convertable to peacetime production. In 1940 the estimated value of output of 1,354 industrial plants exceeded 4 billion Chinese dollars, valued at about $0.055 U. S. in 1940.

DATA ON SELECTED LIST OF CHINESE INDUSTRIES[1] – 1944

	No of Establishments	*Capitalization (Millions U.S. $)*	*Staff*	*Workmen*
Metallurgical	43	30.8	421	6,415
Machinery	77	193.4	767	3,479
Metalworking	49	60.4	336	1,317
Electrical Mfg	13	27.9	96	324
Chemicals	279	409.8	2,814	10,380
Textiles	213	369.9	2,981	22,470
Clothing	16	18.9	161	825
Foodstuffs and Beverages	164	237.3	1,320	3,527
Printing	25	30.6	366	2,321
Miscellaneous	19	15.8	209	826

[1] Chinese Ministry of Economic Affairs

C Z E C H O S L O V A K I A

Enemy occupation of Czechoslovakia lasted for six and one-half years. Battles raged across the country prior to liberation and serious damage was inflicted upon key industrial establishments by Allied bombers. The official estimate of the damages inflicted by war runs to 11.5 billion dollars. Of this, some 4 billion was due to direct physical losses, 770 million to lack of maintenance, while the remainder may largely be attributed to the costs of occupation and similar causes. The figure does not include German currency manipulations which is estimated to have involved a sum of 4 billion dollars.

At the end of hostilities industry was seriously disrupted, transport was at a standstill, and the labor market was disorganized. Recovery has been rapid and the government of Czechoslovakia has outlined a Two-Year Plan for reconstruction. Difficulties in the way of achieving the goals of the Plan are chiefly the loss of productive labor through the transfer of territory and population to the Soviet Union (about 500,000 persons in all) and the transference of at least 2 million Sudeten Germans. The population is thus reduced by nearly 20 per cent – to a little more than 12 million. Fuel and raw material shortages constitute additional handicaps.

In Czechoslovakia's reconstruction plan the greatest emphasis is placed on increased production of capital goods and the expansion of the electric power industry. It is also intended to alter the pre-war production pattern so that industries will be shifted away from the western frontier regions and located in Slovakia. Industry is much less developed in Slovakia, where at mid-1946 industrial employment only totalled 156,678. In spite of the problems involved in such a large-scale transfer of industries and the considerable reduction of the available labor force through German deportations, the plan aims at surpassing pre-war production by 10 per cent.

Concentrated efforts will be centered in the mining, smelting, power, chemical, and engineering industries. The following target figures have been set for Czech industry, to be reached by the end of 1948:

Industry	*Target*	*Comparison with 1937*
Hard coal	16,700,000 metric tons	same
Brown coal	23,900,000 metric tons	+33 per cent
Pig iron	1,400,000 metric tons	– 20 per cent
Steel	2,200,000 metric tons	– 5 per cent
Electricity	7,400,000,000 Kwh	+75 per cent
Railroad cars	15,000 per annum	+1000 per cent
Locomotives	290 per annum	+ 400 per cent
Tractors	9,000 per annum	+1500 per cent
Trucks	10,600 per annum	+ 250 per cent

PRODUCTION OF PRINCIPAL INDUSTRIES – 1946

Products	*Volume*
Black Coal	14,163,888 tons
Brown Coal	19,570,604 "
Coke	2,183,367 "
Iron Ore	1,118,924 "
Coal Gas	232,800,000 m^3.
Castings	216,196 tons
Railway Rolling Stock	11,016 units
Tractors	988 "
Locomotives	140 "
Motor vehicles – passenger	3,795 "
goods	2,498 "
Motorcycles	18,200 "
Bicycles	119,663 "
Machine Tools	7,250 "
Sewing machines	31,234 "
Radio receivers	104,544 "
Telephones	40,332 "
Hollow Glassware	80,484 tons
Sheet and Plate glass	96,528 "
Bricks	373,221,600 units
Tiles	103,765,200 "
Paper	149,085 tons
Cardboard	62,239 "

In addition, 2,400 tons of river shipping are to be produced annually, and 22 million dollars worth of agricultural machinery. Production of synthetic motor fuels is to be expanded nearly 70 per cent above the present level, which is already above pre-war. The output of phosphates for agriculture is to reach a total of 400,000 tons, compared with pre-war production of 287,000 tons. Nitrate production is set for 500,000 tons, compared with 122,000 tons pre-war. Railway and river transport is to be extended and modernized.

DATA ON EMPLOYMENT IN CZECH INDUSTRY[1]

Industry	End of 1937	End of 1944	End of 1946	Rank[3]
Iron and Metal-working	322.5	646.6	338.1	1
Textiles	242.1	171.8	149.0	2
Stone and earthware	92.7	72.4	35.9	6
Mining	83.0	140.8	111.5	3
Food processing	60.8	58.9	54.0	5
Leather-working	54.3	50.5	30.7	9
Chemicals	51.6	93.5	58.0	4
Clothing	50.9	40.4	34.9	7
Woodworking	45.6	52.3	34.3	8
Glass	37.2	35.7	26.8	10
Total, including all other industry[2]	1,197.7	1,526.6	1,050.6	

[1] *Czech Ministry of Foreign Trade, Prague 1947*
[2] *Excludes building trade*
[3] *In order of importance, 1946*

The achievement of the goals set by the Government will require substantial imports from abroad, for which the country needs financial assistance. The metal industry, for instance, will require annual imports of more than 1 million tons of iron ore, 30,000 tons of copper, 20,000 tons of zinc, and smaller quantities of aluminum, tin, and nickel. The chemical industry will require imports of more than 1.2 million tons of raw materials annually.

Trade arrangements since the war, aimed at obtaining supplies for industry and domestic consumers, have included more than a score of bilateral agreements. Also, credits from hard currency countries will permit large imports from the United States, the United Kingdom, and Sweden. Since the end of the war Czechslovakia has obtained 168 million dollars in foreign credits from the following sources:

POST-WAR CREDITS

Source of Credit	Millions of dollars
U. S. Surplus Property Credit[1]	50
Export-Import Bank of Washington	22
United Kingdom Government	20
British private bank	8
British Surplus Property Credit	10
Australian Government	1.6
Canadian Government	19
Swedish Government	6
Brazilian Government	20
Egyptian Government	4
Mexican Government	4
Swiss Government[2]	2

[1] Suspended, mid 1947
[2] Arising from a payment agreement

Recognizing that even these credits will fail to meet prospective requirements, the Czech Government has requested a loan of 350 million dollars from the International Bank for Reconstruction and Development.

In 1946 Czechoslovakia's commercial imports amounted to 321 million dollars and exports to 286 million dollars. The estimate of 1947 trade, made at mid-year, involved imports of 737 million dollars and exports of 590 million dollars. In December, 1947, Czechoslovakia concluded a new one-year trade agreement with the Soviet Union involving an exchange of goods in each direction estimated at about 110 million dollars. At the time of the agreement, the Czech government estimated that this agreement would cover about 17 per cent of Czech foreign trade. It was also indicated that agreements with the U.S.S.R., Poland, Yugoslavia, and Bulgaria together will govern between 30 per cent and 35 per cent of Czech trade in 1948.

CZECHOSLOVAKIAN STATISTICS

Number of industrial establishments *Only 1,500 employ more than 20 workmen*	378,000
Number of people employed in industry, 1947	1,127,807
Iron and steel production, 1946	
Pig iron	959,758 metric tons
Steel ingot	1,672,380 " "
Railroads 1937 (miles)	8,650
Highways, 1947 (miles)	43,700
Inland waterways 1937 (miles)	1,190
Kwh produced, 1946	5,568 million
Trade, 1946	
Imports	$321 million
Exports	$286 "

Includes UNRRA imports which exceeded commercial imports in value. This figure is given by the Economics Section of the United Nations. Official Czech sources set commercial imports at only $205 million

Czechoslovakia will pay in part for its reconstruction by the sale of capital goods. Skilled craftsmanship in metalworking is illustrated by this workman on modern, heavy-duty lathe.

DENMARK

Denmark suffered little material destruction during the war in comparison with other occupied countries The reduction of real assets is estimated at between 5 and 10 per cent The most important direct loss was the destruction of one third of the merchant marine which in normal times was the compensating factor in balancing the country's deficits in trade Despite destruction of some facilities, the railroad system was in fair condition at the end of the war

The most serious effects of the occupation resulted from the blockade Denmark's economy is based upon imports of cattle feed, industrial raw materials and fuel The unavailability of these supplies materially reduced the country's economic activity

Since the war recovery has been keyed to the required imports for the expansion of production and the building up of essential stocks Trade has been resumed with most of Denmark's pre-war customers, but the loss of normal exchange with Germany creates a special problem

A significant part of the country's industrial activities is based upon the industrial treatment of various agricultural products such as the production of condensed milk, preserved meat, sugar, beer yeast, and liqueurs Cooperation between industry and agriculture has benefited both branches of trade This interdependence is illustrated by the importance attained by the manufacturers of machinery for the dairy and meat-packing industries, and food refrigerating plants Danish dairy preparations have an important foreign market

The diesel engine is an important product of the Danish engineering industry The sea-going motor ship and the diesel-electric locomotive constitute part of Danish industry's specialties Many of the large and small machinery manufacturing companies have specialized for the foreign market Among these may be mentioned those making laundry machinery, steam kitchen equipment, grinding mills, refuse disposal plants, sheet-iron radiators, railway trucks, wood and metal working machines, mechanical and hydraulic presses, bottling equipment, road building machines, candy machines, and shoe-making equipment

Denmark has an important shipbuilding industry, engaged in production of vessels for Danish and foreign use, mainly equipped with diesel engines, and other Danish-built apparatus Along with the rapid electrification in Denmark there has developed a substantial industry manufacturing electrical equipment Cement production is of major importance, and Denmark has won a place in world markets for its rotary kilns and tube mills

One of Denmark's most important exporting industries in normal times is the oil industry, which treats raw materials such as copra, soya beans, whale oil, and other primary products imported from throughout the world

Within a year after the end of World War II, Danish industrial production had reached a level almost equal to 1938 as a result of a rise in output of about 20 per cent to 25 per cent Foreign trade has been resumed but Denmark is confronted with a serious long-range problem in its relations with the rest of the world. Apart from needing large imports to restart industrial and agricultural production, while unable to export on a commensurate scale the country faces the problem of high prices abroad for the feedstuffs it needs and low prices for its export commodities

During 1946, Denmark had excess imports of 256 million dollars, with an estimated income of 83 million dollars earned from shipping At mid-year the government imposed trade restrictions aimed at reducing imports by 124 million dollars An effort was made in 1947 to bring trade more nearly into balance. Shipping income is estimated at 74 million dollars and credit balances with other countries will be utilized to reduce the deficit in international payments At the end of 1946 Denmark had entered into trade agreements with 14 countries Spain, Sweden, Belgium, Italy, the Netherlands, Norway, Finland, France, Switzerland, Hungary, Portugal the U S S R, Czechoslovakia, and Poland. These agreements covered trade in each direction amounting to nearly 185 million dollars

From the end of the war until December 31, 1946, Denmark had obtained credits from abroad amounting to 190 million dollars, exclusive of permissible overdrafts on accounts with trade-agreement partners The United States had granted 20 million, the United Kingdom 140 million, and Sweden 30 million Nearly another 100 million dollars have become available through trade

DATA ON SELECTED LIST OF DANISH INDUSTRIES — 1945

Stated in terms of 1000 Danish Kroner
($1 = 4 81 Kroner)

	No of Establishments	*No Employed*	*Value of Production*	*Value of Exports*	*Value of Imports*
Chemical and Allied industries	1,326	28,631	729,776	14,478	97,094
Cement mills and rock products industries	69	1,860	25,780	8,998	1,324
Food processing Industries	1,401	32,137	1,587,988	650,329	85,805
Metallurgical and metal working industries	1,185	53,366	774,196	60,175	93
Electric power generation	413	—	323,000	5,500 KWH	135,100 KWH
Pulp and Paper Industries	196	6,649	143,573	1,426	77,369
Textiles	367	16,775	308,291	4,693	121,350

and payment agreements with other European countries

Although Danish industry had made a substantial recovery from the war, the index of animal agricultural produce stood at only 88 in June, 1947 (production in 1935=100) Cheese (288), milk (106) and meat (102) were above the 1935 level, while butter (96), pork (68), and eggs (76) were well below that level

By mid-1947 industrial production had risen to an index figure of 109 (production in 1935=100) Food processing (130), leather goods (160), woodworking (128) and the iron and metals industry (115) were well above the 1935 level, while textiles (99) and clothing (69), ceramics (90), and chemicals (91) were below

During the first half of 1947, imports exceeded exports by only 82 5 million dollars, or only half the 1946 rate This trend toward equilibrium is expected to continue provided Denmark can obtain adequate fuel for industry and feedstuffs for farm animals

DANISH STATISTICS

Number of industrial establishments	102,296
Number of people employed in industry,[1] 1940	634,340
Railroads, 1946, (miles)	3,021
Paved Highways, 1946 (miles)	5,044
Kwh produced locally, 1941-45	1,451 million
imported, 1944-45	135 "
Telephones, 1946	567,000
Trade, 1946	
Imports	$590 million
Exports	336 "

[1] *According to the* FOREIGN OFFICE JOURNAL, *November, 1946, the employment figure (Average number of workers employed in industry multiplied by the daily working hours) had reached 1,590,000 in August, 1946, compared with 1,287,000 in 1938*

VALUE OF PRINCIPAL MANUFACTURES

Product	*Millions of dollars*
Foodstuffs	304
Iron and metals	160
Chemicals and allied products	151
Textiles	64
Clothing	63
Leather	40
Wood	35
Stone, Clay and Glass	29

EGYPT

During the war years, Egypt was a fighting base for Allied troops in Africa, the Middle East, and the Mediterranean Wartime shortages brought an increase in local production of some products usually imported. But the principal industry in Egypt is still the production of cotton, and textile manufacturing is a steadily growing factor in the economy.

Egypt is the foremost producer of long-staple cotton, accounting for 60 per cent of world's output. One lb of the highest grade of Egyptian cotton will produce as much as 189,000 yd of yarn, while 1 lb of middling American cotton will make only about 12,600 yd. During the war, Karnak cotton was spun into a yarn called "400" – which involved producing from 1 lb of cotton a yarn 400 x 480 I C, 360,000 yd long

During the latest year for which statistics are available, the Egyptian textile industry consumed the following quantities of cotton

Poplin, zephyr, and voile	360,000 bales
Knitting	250,000 "
Thread	150,000 "
Tires	150,000 "
Cotton velvet	40,000 "
Typewriter ribbons	25,000 "
Electrical appliances	20,000 "

During the last decade, domestic consumption of cotton by the spinning industry has increased more than fourfold (1 kantar = 99 05 lbs)

1935 36	395,204 kantars
1939-40	584,000 "
1940-41	753,000 "
1941-42	854,000 "
1942-43	891,000 "
1943 44	875,000 "
1944-45	1,664,000 "
1945-46	1,643,000 "

Production of cotton weaving mills in 1946 amounted to 204,000,000 meters, compared with 130,000,000 meters in 1938.

Production of wool spinning mills in 1946 amounted to 2,000,000 meters, or twice the amount produced in 1938

Mounting the blade system of a 22,500 kw turbine at Kraftverk P. E. B. Bloemendaal, Holland.

EGYPTIAN PETROLEUM AND MINERAL PRODUCTION

	(In Metric Tons)		
	1938	*1942*	*1945*
Petroleum	225,736	1,190,878	1,349,473
Phospates	458,404	327,470	349,374
Manganese	153,112	8,169	47
Iron ores	714	7,100	4,056
Talc	1,251	1,874	3,868
Gold	2,162	1,868	3,014

American trade with Egypt received a boost early in January of this year when the Egyptian and British governments signed an agreement, unlocking some of the former's sterling balance Under the agreement, some of this can be converted into dollars This will assist Egypt in buying needed American industrial equipment, although there were no signs of a U S loan In all, Egypt will be able to use 21 million pounds sterling, of which part will be used to purchase 25 million dollars

FRANCE

The war and the long occupation left a deep mark upon French industry In the period 1940-45, some 150,000 industrial buildings were destroyed or damaged, 300,000 units of rolling stock were lost or destroyed, a large part of the country's port installations and 75 per cent of the merchant fleet were wrecked But of equal importance were losses sustained by the removal of equipment to Germany and the obsolescence of machines

Stocks of goods were reduced to nil, the labor force dispersed, and domestic commerce disrupted Prices soared, despite attempts at regulation, from an index of 100 in 1938 to 375 in 1945

Genessiat Dam on the Upper Rhone will be Europe's second largest and rival Dneprostroy in power output. It is the first of a series of 20 projected power plants to produce 10 billion kwh annually.

At the end of the war, France was faced with the problems of meeting current needs, fulfilling an accumulated demand of five years of austerity, and trying to reconstruct the instruments of production The first job was to get industry started Within a few months transport had been re-established and with it the movement of goods Recovery was less satisfactory in the production of primary materials These required an ample supply of power, which depended upon an increase in coal production The output of coal rose from 35 million metric tons in 1945 to 50 million tons in 1946—a figure comparable to the 1938 level Despite this, during the severe winter of 1946-47 many plants were closed for several days each week because of fuel shortages Lack of fuel affected every branch of industry, and required a careful allocation of supplies

France also faces another problem in the loss of manpower A shortage of skilled workers needed for reconstruction tasks has been particularly acute Employment in administrative and service jobs has grown, depriving industry of supervisory and specialized workmen The loss of prisoners of war aggravated a situation which the lengthened work week of 48 hours has failed to ameliorate

Finally, industry has been so impoverished by war that it lacks funds for expansion and replacement Financial aid has become increasingly difficult to obtain Because of the increasing needs of the state, banks are unable to satisfy the needs of private enterprises

The role of the state has been particularly important in the post war development of the French economy At the outset, the government assumed responsibility for examining the needs of industry, regulating the flow of materials and keeping an eye upon their disposition. Then, when it became apparent that this piece-meal solution really called for an overall plan, the government assumed virtual direction of the economy, fixing for each branch of industry the level of its output, prices, distribution and stocks Strict regulations were imposed governing the use of manpower Finally, under the influence of socialistic ideas, the state took over some industries, nationalized the Nord and Pas de Calais coal mines, electricity, banks and insurance, and assumed strict control in various other economic sectors

This system of controls was not established without its effect upon private initiative Regulations and red tape multiplied, and controls of all kinds tended to hamper private business. Although vigorous intervention by government was generally recognized as essential in the early post-war period, many businessmen felt that the trend was carried too far, with a detrimental effect upon recovery

At the same time, the financial position of the nation was difficult The fiscal capacity of the country was being strained, and equilibrium was only maintained by recourse to currency expansion A major factor in the inflationary situation was the imbalance between various elements in the economy The price of farm products had risen 12 times above 1938, wages had increased eightfold, while the price of industrial products, under strict control, had risen only sevenfold. This disparity in prices constitutes a great menace to the nation's equilibrium.

Late in January of this year announcement was made of the devaluation of the French franc, to bring it in line with the black market rate in "hard currencies." Under this plan, as approved by the Finance Ministry, visitors and tourists will be able to obtain the free market rate (315 frances to the dollar in January, 1947), instead of the previously fixed rate of 119 francs to the dollar The plan also calls for an "export franc" pegged at 216 to the dollar It is hoped that this will permit French exporters to sell their goods in hard currency areas The overall plan aims at eliminating the black market in currency, funneling it back into legal channels.

Although France traditionally has been open to foreign commerce, it lacks exchange resources and has had to place its trade under strict regulation. Imports have been restricted since the war, and exports have been insufficient to pay for the goods needed for reconstruction.

However, the measure of recovery which has been achieved in the two years since the war has been considerable In the following table are some figures which depict the trend

	1938	*1945*	*Rate Based on First 6 Months 1947*
Electricity (millions of kwh)	1,547	1,464	2,126
Coal (thousand metric tons)	3,875	2,780	4,013
Steel (thousand metric tons)	518	138	483
Aluminum (thousand metric tons)	4.2	3.8	6
Sulphuric Acid (thousand metric tons)	106	23	90
Automobiles (units)	15,200	130	6,416
Carloadings	1,248,938	508,262	1,096,440

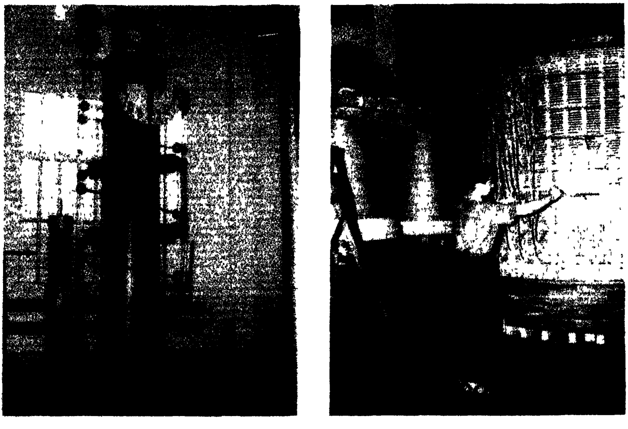
On the basis of these figures it can be seen that France will soon have reached a level of activity parallel to prewar. But this eventuality cannot be envisaged without satisfying certain preliminary conditions. The basic need is still an expansion of present productive facilities and the regulation of their use

The reconstruction and modernization of plants are prerequisites to the rapid achievement of goals which have been set for industry But even these are subject to an over-riding condition: obtaining the materials for production, both primary products and machine tools. France cannot fully exploit its resources until power production has been raised This requires further imports for which the nation lacks funds Therefore, the ultimate condition for French reconstruction lies in obtaining credits abroad.

A shortage of manpower imposes the task of using available workers to best advantage, by increasing their skill and supplying them with the machines needed to augment productivity. France's technological level must be raised. While it may become necessary for the state to regulate the manufacturing economy, it must not overlook the contribution which can be made by private business French industry greatly needs modernization and its cost will come high. It is necessary to diversify production in some industries, to increase specialization in others, and to improve techniques in all of them.

Close-up of Genessiat Dam (above) and perspective (below): It is government sponsored but privately owned. Work begun on the dam in 1934 was destroyed in 1940. Profits from the sale of power are intended to revert to Rhone Valley developments. With the government owning a large share of stock in the project, it is likely that it will become nationalized as an essential part of the country's electrical system.

La Savoisiene at Aix-les-Bains shows in this series of four pictures how their plant is manufacturing the electrical equipment for Genissiat Dam. Illustrated are various stages in the construction of 4 transformers with a 70,000 kva capacity. (Top left) Electric arc welding of the casing and cooling element; (top right) bobbin assembly for covering and insulating the wiring; (bottom left) insulators being submitted to a shock test of 800,000 volts; (bottom right) winding one of the transformers which will be installed at Genissiat.



Although the present level of production presages future advances, the acquisition of new equipment and the introduction of modern techniques will contribute substantially to the success of reconstruction Actually the problem of prices is now more important than the plan A solid currency and a balanced budget are necessary conditions of financial stability needed as a solid foundation for the production machinery

The resolution of political difficulties must also have an important bearing on the future economic progress of France.

A beginning has meanwhile been made by the government to determine the successive steps required to restore the economy This has been elaborated in the *Plan for Modernization and Re-equipment* drawn up by a group headed by Jean Monnet It sets forth the goals for production to be achieved by 1950

The Monnet Plan calls for extensive development of the nation's basic resources In the expansion of electrical production, hydraulic resources will be given primary emphasis The plan envisages expansion of hydropower from 13 billion kw in 1946 to 23 billion kw in 1951 The major projects will include·

(a) *Genissiat*, on the Rhone, between Geneval and Lyon Five 65,000 kw units are to be installed, with an eventual production of 1,540 million kwh a year The first units will be in service in 1948, and the remainder in 1949 and 1950

(b) *Donzere-Montdragon*, on the Lower Rhone First work on this project has begun and it is expected to be in operation in 1951, with final completion scheduled for 1953

(c) *Ottmarsheim*, where 4 units of 36,000 kw capacity will be installed to produce 900 million kwh This project is to be completed between 1952 and 1953

In the table below the principal projects which form a part of the Monnet Plan for expanding power production are listed·

Thermo-electric capacity is also being developed Several thermal stations with 100,000 kw units are in the process of construction

(a) *Gennevilliers*, two units (1 American and 1 French), to be in service 1948, '49

(b) *Carling*, two units, to be in service 1950, '52

(c) *Moselle*, one unit, to be in service 1952

Other stations will be equipped with 40,000 kw and 50,000 kw units Capacity to be installed between 1947 and 1953 will be in excess of 2 million kwh Of particular interest is the station which will power the electric furnaces of steel mills in the Longwy basin.

The most important projects in the iron and steel industry will be the installation of two continuous 66 in strip mills

FRENCH STATISTICS

Number of Persons Employed in Industry, 1946		5,970,000
Number of Industrial Establishments, 1936		526,000
Average Annual Income of Industrial Workers, 1946		$530
Obtained by dividing total wages in 1946 by the total number of workers This does not include family allowances, which amount to about 8 per cent of wages		
Total Capital Invested in all Industry, 1938		$10-15 billion
Iron and Steel Production		
Crude steel, 1938	6,221,000	metric tons
1946	4,408,000	" "
First 6 mos 1947	2,897,000	" "
Miles of Railroads, 1946		38,016
Miles of Highways, 1939		
National		50,000
Departmental		158,000
Local		185,000
Millions of kwh Consumed		
First 6 mos 1938		9,838
First 6 mos 1946		10,818
First 6 mos 1947		7,131
Number of Telephone, 1946 (A T & T data)		1,879,500
Foreign Trade, 1946 47		
Including trade with French colonies		
Imports	$1,950	million
Exports	845	"
First 6 mos 1947		
Imports	1,389	"
Exports	889	"

HYDRO-ELECTRIC PROJECTS UNDER MONNET PLAN

	Number of Units	*(1000 kw)*	*Annual kwh (Millions)*	*Date to be in Service*
L'Aigle	3	150	500	1947, '48, '49
Genissait	5	325	1,540	1948, '49, '50
Chastang	2	170	500	1950
Le Pouget	3	120	300	1950, '51
Passy	4	92	285	1950, '51, '52
Brevieres	3	96	160	1951, '52
Malgovert	4	320	340	1951, '52, '53
Roselend	4	260	300	1952, '53
Aiguebelle	3	110	480	1952
Bort	2	180	180	1951, '52
Cap de Long	3	195	350	1951, '52
Ottmarsheim	4	144	900	1952, '53
Donzere	4	180	1,350	1951, '52, '53

PRINCIPAL GOALS OF FRANCE'S FOUR-YEAR PLAN —1947-50

	1929	*1938*	*1945*	*1946*	*1947*	*1948*	*1949*	*1950*
Coal and Lignite (million metric tons)	55	47.6	35.1	50	55.5	59	62	65
Electricity (billion kwh)	14.4	20.6	19.1	23.5	26	30	33	37
Steel (million metric tons)	9.7	6.2	1.5	4.2	7	9	10	11
Cement (million metric tons)	5.3	3.8	1.5	3	6	8	11.5	13.5
Tractors (thousands)	—	2.7	1.3	1.7	12.3	—	—	—
Cultivators (thousands)	—			1.5	6	—	—	16
Refined Fuels (million metric tons)	2.8	6	0.6	2.8	1.9	—	—	8.1
Textiles Cotton Thread (1000 metric tons)	246	220	62.5	150	220	—	—	280
Flax Thread "	-	25	7.7	18	28	—	—	42
Wool Thread "	117	100	56	110	120	—	—	140
Rayon Thread "	—	25	6.1	19	36	-	-	46

(a) At Nord à Denain, being equipped by the United States firms United Engineering and Westinghouse, to be in service in 1949.

(b) At Havange, discussion of which is now under way.

In the field of mechanical industries, a 36,000 ton light-metal mill is being built with American equipment at the d'Issoire works. To satisfy the important needs of agriculture, a tractor plant of 50 000 unit capacity (by 1950) is being erected. At present, the only source of production is the nationalized Renault plant with an output of 500 units a month.

In the chemicals field, several important developments are under way. The production of nitrogen will be raised to 550,000 tons by 1951, as against the present level of less than 200,000 tons.

A plant for the extraction of magnesium from sea water is to be built at Ponteau with capacity of 40,000

FRENCH INDUSTRIAL PRODUCTION
1946

(Dollar figures based on exchange $1 = 120 francs)

Industry	*Number of Establishments*	*Number of Workers and Employees*	*Number of Concerns*	*Value of Exports[1] (In Millions U S Dollars)*	*Value of Imports[1] (In Millions U.S Dollars)*
Mines					
Coal	*	351,000	414	10	94
Others	110	32,000	46	45	7
Gas	*	40,000	110	n a	n a
Liquid Fuels	n a	30,000	396	2	123
Electricity	*	70,000	242	—	6
Metallurgy	200	142,350	280	12	114
Metal Working	2,650	142,400	374	n a	n a
Mechanical and Elec Industries					
Automobiles	570	162,000	437	34	41
Railroad Equip	83	45,000	—	—	—
Elec Const	1,132	158,000	—	—	—
Other Mech Industries	n a	700,000	—	—	—
Chemical Industries	n a.	121,000	480	38	103
Rubber	270	53,000	183	4	24
Glass	1,100	33,500	67	7	2
Pharmaceuticals	1,900	23,000	n a	7	4
Construction Mat	4,300	138,000	255	—	—
Lime & Cement	420	20,000	61	11	13
Stone	n a	64,000	107	—	—
Ceramics	1,320	54,000	87	—	—
Foods	1,200	485 000	794	141	32
Textiles					
Fabrics	14,000	532,000	1,540	116	268
Clothing	58,000	208,500	430	8	10
Paper, etc	290	71,000	183	9	53
Others	—	—	—	62	82
Total	500,000	5,970	—	566	1,519

N. A — Not available. * Nationalized industry. [1] Millions $ U S

PRINCIPAL INDUSTRIES AND VALUE OF PRODUCTION – 1946

	Millions $ 1946
Textiles	1,540
Food Processing	794
Chemicals	480
Automobiles	437
Clothing	430
Coal Mining	414
Liquid fuels	316
Electrical Products	384
Metal Working	374
Leather	342
Production of Metals	280
Electricity	(242)

OCCUPATIONAL DATA – 1938, 1947 AND 1950 (PLAN)

	(Thousands)		
	1938	*1947*	*1950*
Coal Mining	260	–	312
Iron and Steel	160	140	170
Automobiles	121	100	128
Construction Materials	69	94	110
Textiles	720	560	665
Building and Public Works	960	1,050	1,240
Agriculture	7,140	6,600	6,250

tons a year – enough to cover the country's needs, while allocating a part of production for export

Two wood processing plants are being built in Landes and Strasbourg with material obtained from Germany as reparations

In addition to striving for increased production of coal from existing fields, the important reserves of Lorraine, which are readily susceptible to mechanization, are being exploited. At Faulquemont and Saint-Avold, where an expansion program was under way when the war started, facilities were sabotaged by the Germans and have not been restored Their capacity is 18,000 tons daily.

New pits at the Loire field have been equipped since the war In the lignite field of Bouches du Rhone, new pits are being put into service

In the modernization of French industry, various foreign firms will play an important role Standard Oil, Royal Dutch Shell, and Vacuum Oil are assisting the oil industry The Ford Motor Co is expanding facilities for the production of motor cars Dunlop and Goodrich are helping to expand tire production. Belgium and Luxembourg are helping with reconstruction of the iron and steel industry. The firms of Sulzer-Singer, Kennedy, Thomson and others are undertaking projects to boost the output of electrical products and other manufactures. Massey-Harris and International Harvester are expanding production of farm machinery. Solvay and Ciba will aid in raising the chemical output. And production of shoes will be expanded by Bata and Bally.

GREAT BRITAIN

Industrial expansion in Britain since the war has been almost exclusively concentrated in Government-sponsored development areas. There are six such areas which in the year before the war were known as *Special* (or *Depressed*) *Areas*, experiencing heavy and prolonged unemployment. Under the Distribution of Industry Act, 1945, the Government was empowered to develop certain specified areas and secure a balanced distribution of industry over the whole country The Government not only acquires the land for such development but is authorized to prepare sites for factories, to erect buildings and to house key workers Factories are leased or sold to the occupants

Since the war it has been compulsory to notify the Government of all industrial projects, and permission to build factories is granted only after careful consideration has been given to possible location in one of the Development Areas Accordingly, under this policy many of the new projects are being located in these areas

Official figures given by the Government on June 19, 1947, covering the period from July 31, 1945, to April 30, 1947 revealed that the number of new factories and extensions (more than 5,000 sq ft) approved in Great Britain was 2,483, of which 770 were in the Development Areas It was estimated that when all these factories were in full production they would employ 289,180 workers, of which more than half (151,700) would be in the Development Areas In the Development Areas 138 factories had been completed, and 461 were in course of erection

The number of Government owned factories (including former Royal Ordnance Factories) allocated for civilian production totalled 269, of which 56 were in the Development Areas In 12 Government-financed, and 26 privately-financed factories in the North East Development Area, actual production has now begun In the same area 22 Government-financed and 25 privately-financed factory schemes are now under construction (Details of location, name of firm, area occupied and products are available from "The Development Areas Today," H M Stationery Office, 1947.)

One of the most important of the Special Areas projects is that of Imperial Chemical Industries Ltd. in Teeside in the *Northeast Area*, for the extension of their chemical products capacity. At the end of ten to fifteen years they expect to absorb 10,000 workers. One of the largest privately-financed schemes completed since the war in this Area is the new factory for De La Rue Insulation Ltd, makers of laminated plastic board for heavy electrical industries, railway wagons, housing. O. & M. Kleeman, Ltd, makers of plastic fancy goods, employ 1,000 workers; in another factory Smart & Brown (Engineers) Ltd. make household electrical components, employing 660 workers. Prices Taylors Ltd are expanding and expect to employ 1,000 workers at each of three new factories in the area. Siemens Bros & Co. Ltd. aim to produce industrial electric light fittings and automatic telephone exchange equipment in a factory to employ

1,450 men, and are transferring the whole of their dry battery production at Woolwich to another factory where they are already employing 900 workers Patons and Baldwins Ltd intend to center all their knitting wool production at Darlington with employment at somewhere between the 1,000-2,000 level.

In general the types of production which will go this area include 51 clothing firms, 76 engineering firms, 62 electrical and metal goods manufacturers, 21 textile makers and 15 plastic firms with individual factories for tobacco, furniture, chemicals and paper converting

In the *West Cumberland* Area 9 factories have been completed and production commenced giving employment for 1,550 workers, and a further 24 projects have been approved, work having commenced on 14 The largest projects by space occupied are those of The Distington Engineering Co Ltd at Workington for the manufacture of mining machinery and steel castings, M Hackney & Co at Aspatria, for furniture and bedding (both occupying 104,800 sq ft) Among the building schemes not yet started is one for A S P Chemicals Ltd at Workington to cover 120,000 sq ft for the manufacture of chemicals

The Distington Engineering Co have taken over a former Government munition factory and are making iron castings for the steel trade at the rate of 800 tons a week They are extending their output in an ingot mould factory, a steel factory, a pattern shop and engineering works for the manufacture of mining equipment under U S patents More than 800 men are now employed The peak employment will be about 1,500

High Duty Alloys Ltd, new to the Area during wartime have switched from aircraft components to aluminium houses and in the foundry are turning out 530 tons of alloy billets per week for all purposes They now employ 1,200 workers When full production is reached employment will total 1,600 workers

A big undertaking in its early stages is the conversion of a Royal Ordnance Factory at Sellafield into a large rayon producing unit for Courtaulds Ltd which will eventually employ 2,500 workers The British Bata Shoe Co. Ltd. employ 400 workers in an ex wartime factory at Maryport.

In South Wales 25 new factories have been completed, and 107 new factories and extensions are under construction for known occupants In addition, 34 factories are under construction for industry Of the Government-financed schemes 21 have been completed and employ about 2,400 workers in a wide variety of industries Similarly 10 privately-financed schemes have been completed. Of the 259 schemes approved, work has already begun on all except about a dozen of the schemes occupying more than 30,000 sq ft.

A large Royal Ordnance Factory at Bridgend and Hirwaun have been converted into industrial estates The former, one of the largest wartime Royal Ordnance Factories (a shell filling factory) is now occupied by 74 out of the 80 firms who have been allotted 750,000 sq ft of space. At the small Royal Ordnance Factory at Hirwaun 25 of the 30 firms allotted space are now in production.

The chief of the trading estates in the *Scottish Area* is at Billington covering 370 acres Pre-war there were 90 factories here Today 60 further projects are being developed In the whole area, of the 336 major schemes approved, 61 new factories have been completed and production commenced. More than half (181) have been financed by the Government Some 36 firms too have been allotted space in Government-owned war factories, and 19 of them are in production. In the completed schemes employment is now being given to about 2,750 people

Among the approved schemes are 89 projects which will ultimately employ 33,800 people The largest of the completed schemes is the National Cash Register Co. occuping an area of approximately 120,000 sq ft at Dundee which has been in production for nearly twelve months Employment is now being given to some 600 workers and it is expected that when further extensions are completed (adding another 175,000 sq ft) and production is in full swing some 1,500 people will be employed

Among the approved projects there are many much larger schemes, some of them double the size of the National Cash Register Co These include 300,000 sq ft factory of Associated British Oil Engines Ltd for the manufacture of industrial engines at Winshaw, the 311,000 sq ft factory for Colvilles Ltd at Motherwell for the production of steel ingots, the 301,600 sq ft factory for Vactric Ltd at Newhouse for electrical equipment, the 270,000 sq ft factory of Boots Pure Drug Co Ltd at Airdry for medical supplies and two schemes for cigarette manufacture, one covering 482,000 sq ft at Glasgow for the Imperial Tobacco Co and the other covering 210,000 sq ft at Larkhall for the same company In all to date there are 22 schemes among the approved projects which will occupy more than 100,000 sq ft

Other large factory and industrial development schemes A modernization and development program for iron and steel drawn up in 1945 and submitted in outline to the Government called for an expenditure of 675 million dollars at prices then prevailing The scheme has now been revalued at something in excess of 800 million dollars on the basis of a 20 per cent increase in costs in the last three years About two-thirds of the plan has been worked out in detail and to date schemes valued at 500 million dollars have been approved by the Government, work having started on schemes totalling about 350 million dollars The schemes involved were to be started over a five-year period and completed in seven and a half years Most of the major schemes will take approximately three years to complete Among the main schemes already approved is the new steel works at Margam, South Wales, for the Steel Co of Wales at a cost of 200 million dollars It will have furnace output sufficient for the new continuous strip mill which will produce approximately 1 million tons a year of mild coiled strip as a basis for continuous cold rolling into tin plate and sheet The first new blast furnace in connection with this plant is already in operation. Site preparation work is proceeding on the remainder of the scheme. A universal beam mill is to be incorporated in the new steel works of Dorman Long for the manufacture of broad flange beams on a site between Redcar and Cleveland in Durham The capacity of the beam mill will be 375,000 ingot tons a year Extensions have been approved to the steel melting shop of John Lysaght & Co Ltd at Normanby Park, Lincolnshire, together with the laying down of a modern continuous billet mill with 450,000 tons (billets) capacity per annum Considerable progress has already been made and expanding production ready for the new mill

At the new melting shop at the Appleby-Frodingham Works of the United Steel Co in Lincolnshire construction is well advanced and it will probably be in operation by the end of 1947 The Round Oak Steel Works of Birmingham are being rebuilt and enlarged to replace two obsolete melting shops by a modern shop by a total capacity increased to 250,000 ingot tonnage per annum This modernization, based essentially on scrap arising in the Birmingham Area has been started.

Approval has been given but work not yet commenced on the expansion of production by Stewarts and Lloyds at Corby, Northamptonshire for the expansion of production by more than 700,000 tons of steel (mainly basic bessemer quality).

In the blast furnaces, schemes have been submitted for an increased capacity of 2,775,000 tons and those approved include the extensions in connection with the Margam Steel Works, Lysaght & Co of Lincolnshire, two new blast furnaces at the Appleby-Frodingham Works to replace smaller units, two furnaces at Consett on the North East coast, another at the Clyde Iron Works in Scotland and developments at Colby

In lighter rolling mills, schemes have been approved for new bar and rod mill integrated with the continuous billet mill at Lysaghts, Lincolnshire, for further strip production at Stewarts & Lloyds, Colby, and a rod mill at Richard Johnson & Nephew at Manchester A new window section mill at Darlington (for Darlington Simpson Rolling Mills) is coming into production.

Plans have been announced for the extension of the Sheffield works of Firth-Vickers Stainless Steel Ltd., a joint subsidiary of Thomas F. and John Brown and the English Steel Corporation, including the erection of a new cold rolling sheet mill The capital of the Company has been increased by 7 7 million dollars to finance this development.

Side by side with these expansion schemes, arrangements have been made to convert approximately one-third of British steel furnace capacity at present using producer coal to the use of liquid fuel. The changing over of this high proportion of plant may save up to about 1,800,000 tons of coal per annum, or approximately 10 per cent of the overall coal required in these processes.

In the glass industry a new sheet glass tank has been built at a cost of 2 million dollars by Pilkington Bros., Ltd., at St Helens, Lancashire It commenced production in January 1947 and is part of the firm's five-year plan which will increase the labour force from 1,800 to 12,400 workers

To support the increasing needs of industry and domestic consumers the Central Electricity Board has plans for 14 new power stations for the years 1951-52, involving an expenditure of nearly 760 million dollars, with an output of 3 9 million kwh by the winter of 1952 At present work is in progress on earlier extension schemes which provide for 17 new generating stations with output of 6 million kwh by the winter of 1950.

North of Scotland Hydro Electric Power contracts totalling more than 50 million dollars have recently been placed by the North of Scotland Hydro Electric Board as part of their hydro-electric development program covering 10 to 15 years, at an original total estimated cost of 260 million dollars, now likely to be much exceeded The capacity of the hydro electric generating plant ordered totals more than 374,000 kwh together with diesel generating sets with a total capacity of 17,500 kwh The main projects include Loch Sloy Dam and Generating Station (capacity 130,000 kwh), the river Frrochty dam and station (capacity 75,000 kwh), the Clunie station (57,000 kwh), the Pitlochry dam station (16,000 kwh), the Fannich catchment scheme and station with 24,000 kwh capacity; and seven distribution schemes serving 141 towns, villages and hamlets including the connection at the Island of Bute to the mainland by submarine cables and the linking of Bute with Cumbrae by a two-mile submarine cable

There are two developments schemes for coal in progress—short term and long term In the short term program maximum output is being expanded as quickly as possible and blanket orders have been placed for new coal face machinery including Meco-Moore cutters, to the value of 40 million dollars Since the National Coal Board took over the mining industry 13 Meco-Moore machines have been installed in eight months Twelve more are to be installed by the end of 1947, bringing the number then in use up to 61 The long term re-organization envisages at least one plan for a major reconstruction project in each of the 49 areas controlled by the Board. It is hoped to commence not less than 20 of them in 1948 and the remainder in subsequent years. Each of these major reconstructions may cost anything up to 12 million dollars each and may take as long as six years to complete New sinkings have been planned and two of them, at Rothes in Fife, and Calverton in Nottinghamshire, have begun Drift mining, to develop seams lying at shallow depths which can be quickly brought into production. There should be 70 schemes at work within the next few years with a total output of 304 million tons per annum. In Scotland 30 or more small mines are under such development

Some of the major projects in the chemical industry include Imperial Chemical Industries which in 1946 began a 40 million dollar expansion of their dyestuffs interest that will eventually give permanent employment to 2,000 or more workers Of this mount £8 million will be allotted for the expansion of manufacturing facilities at Blackley and Trafford Park, Manchester, at Grangemouth, Stirlingshire and Huddersfield. The first three are mainly concerned with dyestuffs; the Huddersfield factory—the largest of its type in the Empire—is concerned mainly with intermediates. The balance of 5 million dollars will be spent on extending facilities for research and testing. At the Blackley Headquarters of the Dyestuffs Division the previous announcement had been for a 40 million dollar project in connection with the Wilton (Teesside) works of I.C.I. for the production of fertilizers and heavy chemicals in general. I.C.I. will probably complete by the middle of next year their new plant at Billingham, Co. Durham, for the production of "nylon salt," the raw material for the manufacture of nylon yarns. It will have a capacity of 5,000 tons a year.

Important new projects are being undertaken for the manufacture of chemicals from petroleum. Work has already begun at an 85 acre site at Thorntonle Moor, Cheshire for the Shell Petroleum Co. Ltd. and the plant which will cost several millions will have an initial production of 24,000 tons annually of a wide range of chemical solvents. At Shell's specialized refinery at Stanlow on the Manchester Ship Canal, production has recently been increased from 12,000 tons to 24,000 tons. An order for sodium higher alkyl sulphates, and a further expansion in the near year or so to 50,000 tons is planned. The existing plant at Shellhaven, Essex, for the manufacture of insecticides and fungicides and other agricultural products will result in an output of 30,000 tons a year. The output of the new plant at Thorntonle Moor will partly replace products at present imported from U.S.A. (equal at present price levels to about 15 million dollars a year). Owing to its modern character the operation of the new plant will make only a small demand upon manpower (about 200 workers and staff) resulting in an output per employee among the highest of Britain's basic industries. Other Shell developments will permit an expansion in exports—virtually a new export trade for Britain.

More recently the Anglo-Iranian Oil Co. has announced that it has concluded an agreement with the Distillers Co. (whose main export is whisky) to form jointly a new company to engage in the manufacture of chemicals from petroleum. The capital is estimated to be £5 million. The Anglo-Iranian Oil Co. already has two refineries in the United Kingdom—one in Wales and one in Scotland.

The main problems connected with the resumption of civilian production in Britain after the war were (a) removing war equipment and re-installing machinery for peacetime production, (b) modernizing eqiupment and buildings, (c) repairing or reconstructing damaged or destroyed factories, (d) preparing new products and designs to meet competition and take advantage of technical advances; *(e) expanding and up-grading the labor force*, (f) deconcentrating industry which had been *concentrated* for efficient wartime production, (g) securing sufficient coal to meet expanded industrial demands; (h) meeting increased industrial and domestic demand for power and gas, (i) finding capacity to produce capital equipment for home and export markets, and (j) regaining and extending export markets.

Owing to the loss of overseas investments and income from other services (shipping, banking, insurance, etc.), there has been a critical decline in income from "invisible" exports with a consequent need for greatly expanded commodity exports. A complicating factor in this connection has been the dollar shortage throughout the world, in part due to the tremendous industrial productivity of the United States, the loss of Europe's productive capacity, the loss of Europe's output in foodstuffs with consequent increased demands upon the Western Hemisphere, and not least in importance, the United States' measure of self-sufficiency which makes it largely independent of imports of the type available from Britain and the Empire. Thus, even when Britain balances her trade with the rest of the world, her account with the U.S. will, even at present low import levels, still show a large deficit. Increased industrial output in Britain will not alone solve the problem, for it is not likely that the United States market will be able to absorb enough of Britain's export production to balance the trade account.

The many reconversion problems that have faced Britain has forced her to sacrifice much of her production for export. Immediately after the war it had become apparent that exports had to be stepped up to 175 per cent of 1938 to restore the country's pre-war living standard. A 20 per cent step-up had been achieved by the end of 1946, but owing to the severe winter and the breakdown of coal and fuel production, this increase was not maintained. The new plan calls for a 40 per cent increase in exports by mid-1948, to be followed by the end of 1948 with an increase to 160 per cent of pre-war export volume.

This program compels Britain to sacrifice many of her capital investment programs—to the extent of about 50 million dollars a year. Priority, however, is still to be given to the coal mining and power generating industries which are basic to present an expanded industrial output. In all capital equipment manufacturing industries definite export targets have to be met even if it means retarding re-equipment programs.

Despite severe shortages at home in all kinds of textiles, the textile industry, with a labor force which has dropped 25 per cent over the war years to about 750,000 workers, must nevertheless increase its exports.

Capital equipment and textiles are among the very few British commodities which can be exported freely to most countries of the world. Export of less essential products is being severely restricted by import regulations abroad. This applies particularly to the motor car industry which had made substantial progress and whose exports (including commercial vehicles) had been at the rate of over $250,000 a week during the eighteen months beginning January, 1946. The motor industry produced 138,000 *cars in the first six months of 1947*, and during the three months May-June, 1947, had achieved an export level which was 220 per cent of 1938. Its future targets are 361 per cent of 1948 by mid-1948, rising to 463 per cent by the end of that year. For the commercial vehicle industry, which at the end of 1946 had achieved 430 per cent of the 1938 volume, the mid-1948 target is 632 per cent and the target for the end of the year is 815 per cent. British car exports set an all-time record in July, 1947, with shipment of 13,800 vehicles (out of a total production of 25,000).

The pottery industry, severely "concentrated" during the war, is not yet back to its full complement of establishments and may never be so, in view of the closing of many small factories and the merging of others The problems of this industry have been examined by a group of experts chosen by the Board of Trade The most important conclusion of the study was that production-line methods and semi-automatic machinery should be widely adopted Despite manpower difficulties, the industry is now believed to be in a leading position as an exporter In the peak pre-war export year, 1937, it shipped 16,300 tons of pottery monthly In 1946 it had reached a monthly export level of 14,300 tons, with the peak month, December, 1946, marking shipments of 20,600 tons In the early months of 1947 there was a decline, due to fuel scarcities In August, exports had risen again to 14,300 tons

The textile industry, severely handicapped by a shortage of manpower, is now endeavoring to meet pent-up home demand and the insatiable requirements of overseas countries Study groups of the Board of Trade, looking into cotton and woolen textile production, have recommended substantial re-equipment based on the continuing shortage of workers.

The number of spindles running in the industry in June, 1947, was 20,900,000 (weekly average) compared with 39,300,000 in the immediate pre-war years The production of woven fabrics for the year 1946 was equal to 31,300,000 linear yards (weekly average) compared with 70,000,000 linear yards in 1937 On the other hand, production of rayon, nylon, and other yarns, averaging 14,950,000 lbs monthly in 1946, was considerably above that level in 1947 In July production amounted to 18,210,000 lbs This compares with 1939 monthly production of 14,500,000 lbs.

Production of woven wool fabrics, for which complete figures are not available on pre-war production, has been stepped up considerably since the end of the war For the year 1945 the total woven wool fabric production was an average of 16,090,000 linear yards per month In 1946 it was 18,600,000 linear yards per month, and in the first six months of 1947 the average was 17,750,000 linear yards monthly

To sum up for the cotton industry, its production is still not more than two-thirds of the pre-war volume and its exports are less than one-half It has embarked upon a program of re-equipping the spinning section of the industry with the encouragement of the Board of Trade, the British Government having offered a 25 per cent grant toward re-equipment costs—subject to orders being placed within two years and of deliveries being completed within five years. The labor force of the industry has also agreed to more intensive working, with the likelihood of double day shifts being introduced. Meanwhile the textile machinery industry, which before the war exported up to 90 per cent of its output, is still expected to contribute much of its production for export and at the same time to re-equip home industry The problem of securing the right balance is one which is being given much attention today.

The steel industry has made a spectacular recovery and its weekly average production is well up to, and sometimes, in excess of pre-war levels. The June, 1947, output of steel ingots and castings, for instance, was at the weekly average of 254,000 tons compared with 250,000 tons per week in 1937 The average weekly production for the first seven months of 1947, despite the fuel crisis earlier in the year and the summer holiday months, has been 227,000 tons In steel sheets the industry has done still better, having exceeded the 1937 level by a small margin

UNITED KINGDOM STATISTICS

Employed in industry, June, 1947	18,360,000
(Only manufacturing	7,054,000)
Industrial establishments[1]	70,000
Average annual income of workers[2]	$1,076
Iron and steel production, 1946	
Pig iron	7,761,000 (metric tons)
Steel ingots and castings	12,693,000 (metric tons)
Railroads, miles	70,000
Highways, paved	180,000
Kwh produced, 1946[3]	41,244,000,000
Telephones, 1947	4,500,000
Trade, 1946	
Imports	£1,297,682,580
Exports[4]	£962,054,683

[1] Excluding coal mining and establishments employing less than ten persons

[2] Based on average weekly earnings, April, 1947, of $20 70

[3] Annual rate, first eight months of 1947 45,500,000,000 Kwh

[4] Including exports of imported merchandise valued at £50,348,445

For the future the steel industry is aiming to reach a target of 16 million tons per year, of which 13 million will be used at home and 3 million tons will be for export In the week ending October 4, 1947, steel output reached an annual rate of 14 2 million tons

Britain's immediate industrial and export achievements are governed by its coal production capacity In the immediate pre-war period, the peak production was 239 7 millions tons per year. This had declined to 180 7 million tons in 1946 The target set for 1947 was 200 million tons, and official estimates toward the end of the year were for an output of 197,000,000 tons. In 1948 it is hoped to improve upon this figure to an extent which will enable a small part of production to be set aside for export in connection with the European Recovery Program (the Marshall Plan). Upon coal production, too, will depend the generation of electricity. In 1938 this was at the monthly rate of 2,031 million kwh. In 1946, industrial and domestic requirements had necessitated a great expansion to 4,437 million kwh per month New generating capacity is being provided, but in the meantime "shedding of the load" is still a threat to domestic and industrial consumers at peak hours. Efforts are being made, as a temporary measure, to stagger the peak loads by spreading out industrial peak consumption.

Coal, steel, and exports are the factors which will govern the outlook of British industry for a number of years to come. In coal the problem is to produce sufficient tonnage to meet not only home and industrial demands but also to restore Britain's vanished export trade in this commodity. Part of the home demand is satisfied by the electrical and gas manufacturing industries Steel, with its short- and long-term development program, is favorably placed for meeting the demands upon it, subject to the availability of equipment for the development program. There is also a call for metallurgical equipment in export which will impair the industry's program of modernization and expansion.

The late-summer crisis in Britain's balance of foreign payments revealed that the trade balance with the world was unfavorable to the extent of nearly 150 million dollars a year (at the monthly rate reached at mid-year) The problem was further aggravated by the much heavier adverse balance with the dollar and hard-currency countries (chiefly the United States, Canada, Portugal, Switzerland, Sweden, Argentina, together with certain other Latin American countries) This hard currency deficit totalled more than the world balance deficit, and was between 175 and 200 million dollars Favorable balances with the rest of the world reduced the over-all imbalance to around 150 million dollars The solution of the dollar problem is a world problem, and is being tackled in Europe through the agency of the Marshall Plan The steps taken in Britain to adjust her balance of payments problem include (a) cuts in imports amounting to 57 million dollars, plus (b) the setting of new export targets to make up the 93 million balance of the deficit

Employment in Principal Manufacturing Industries

	Mid 1947	*Mid 1939*
Building and Civil Engineering Construction	1,136,000	1,206,500
General Engineering (mainly machinery, etc)	956,100	704,700
Textile Manufacture	760,000	987,900
(includes cotton, woollen, silk, rayon, nylon and hosiery industries also shown separately below)		
Coal Mining	738,000	761,200
Road Vehicles and Aircraft Manufacture	558,000	473,300
Road Transport Services (passengers and goods)	486,000	410,900
Food Manufacture (not agriculture, excl drink)	396,200	428,600
Clothing Manufacture (excl boots and shoes)	395,200	496,100
(includes tailoring, and dressmaking industries shown also separately below)		
Shipbuilding & Marine Engineering	279,600	196,900
Electrical Apparatus, Cables, etc (consumer goods)	272,000	195,900
Chemicals, Paints, Explosives, etc (incl Plastics)	268,200	284,200
Printing, Publishing & Bookbinding	265,800	304,300
Cotton Spinning and Weaving (part of Textile Manufacture group given above)	257,000	339,900
Iron and Steel Manufactures (incl tubes)	241,400	232,300
Woodworking Industries (furniture, 114,200)	236,000	240,000
Gas, Water and Electricity Supply	226,500	214,800
Tailoring (part of Clothing Manufacture group already given above)	210,000	234,600
Pottery & earthenware (63,000), glass and products; bricks and tiles (68,600)	187,300	211,600
Leather goods and tanning, and boots and shoes (119,800)	176,700	208,000
Woolen textiles (Part of main Textile Group) .	165,000	207,600
Electrical Engineering (mainly capital equipment)	156,500	133,900
Silk, Rayon, Nylon, etc , and Hosiery (81,400) (part of main Textiles Group)	143,100	198,600
Paper and Board Manufactures .	128,900	159,900
Drink Manufacture	123,400	120,900
Dressmaking and dress industries	102,300	138,600

It is recognized that in the short period of time available it will not be possible to expand production to provide additional exports without reducing supplies to the home market The only alternative is reduced home consumption of both consumer and capital goods To implement the new export program it will be necessary, as has already been mentioned, to reduce capital investment at home by about 50 million dollars The magnitude of this cut can best be guaged by the fact that it is about equal to half of the steel industry's proposed modernization program In pursuing this course, Britain is fully aware that it is sacrificing vitally needed equipment on the home front However, the alternative would be to fall disastrously short of export targets, since overseas countries are encountering balance of payments problems of their own and are restricting imports to goods of an essential nature Thus, motor car imports are being curtailed, but the import of capital equipment is still recognized as essential for industrial modernization and development The main exceptions to Britain's expanded export program of capital goods is that coal and power generating equipment is being retained for home development To a lesser extent, equipment for the textile and chemical industries has a home priority tag

Subject only to a solution being found for the immediate balance of payments and dollar shortage problems, the short term outlook for British industry in 1948 is virtually that of an assured market for all production, at first for the requirements of overseas markets, and once the trade account has been balanced, for all types of products, luxuries included, in home and other markets. Without balancing trade accounts, the prospect is dismal in the extreme, starting first with additional import cuts—food would be the first, followed by raw materials. Once supplies of imported raw materials had been reduced, the descending spiral would operate. Materials would not be available to make goods for export, thus necessitating further import cuts, and so on.

The problem for Britain in the long run—assuming a solution of payments problems and an expanding world level of production and trade—will be that of securing greater production with a declining labor force. Two wars have had their effect on the birth rate. Britain's population is growing older It is now inevitable that increased production capacity must be developed through more efficient production, better machines, etc , and not through the employment of greater numbers of workers to produce the same per capita output as in past years. Britain's dire necessity now to export capital equipment may ultimately be to her advantage insofar as it enables the rest of the world to build up industries with present-day equipment, leaving Britain to re-equip at a later stage with the better and more efficient machines which must emerge in the course of time through research and experimentation. Some machines now being exported to secondary industries in other countries may be out of date in as little as five years, by which time Britain may be in a position to start an all-out drive to re-equip old factories with new equipment.

INDIA AND PAKISTAN

Although the war directly touched India only in its northeastern corner, the Andaman and Nicobar islands, and involved several coast cities in minor air raids, the country emerged from the war with great damage to its manpower and resources. India's military casualties were about 180,000 killed, wounded and missing. It is estimated that 130 million Indians suffer from undernourishment even under the best of peacetime conditions, so that a poor harvest coupled with elimination of rice imports from Burma has had tragic results. The famine in Bengal resulted in 1,500,000 deaths

Despite serious food and materials shortages, India made great gains during the war which will prove in the long run to outweigh losses Many entirely new industries were started and a few existing industries were expanded. Together, these will form an important nucleus to the planned industrialization of the nation

However, in the first post-war years, inflation has affected India more seriously than any other non-devastated country Wholesale prices, which stood at 113 in 1940 (1937 = 100), had risen to 274 by the middle of 1947. The cost of living in Bombay, which stood at 106 in 1940 (1937 = 100), was at 258 in April, 1947.

Industry, after reaching an unprecedented output in the war years, declined in 1947 due to a combination of causes: poor distribution, shortages, and social disorders. Partition of India late in 1947 occasioned extensive unrest with serious repercussions upon the national economy.

Despite this, plans for raising the production level and living standards of the sub-continent have been drafted and will be pursued by the separate governments. They are laid upon a solid basis of industry which has been slowly but steadily expanding for many years and received a sharp boost during the war.

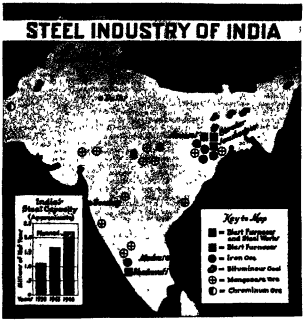
Independence has changed the economic pattern in India The new Pakistan is less of an industrial state than its partner. The statistical picture resulting from independence of the two areas is as follows:

	Pakistan	*India*
Industry (in no of plants)		
Cotton mills	9	380
Jute mills	0	108
Sugar mills	10	156
Iron and steel works	0	18
Paper mills	0	16
Glass works	2	77
Agriculture (in 1000's of acres)		
Jute	1,404	984
Cotton	1,630	13,770
Tea	97	641
Rice	5,376	17,229
Wheat	2,785	4,200
Sugar	517	2,631
Railroad mileage	15,542	25,970
Highway mileage	49,863	246,605

It is too early to assess accurately the development problems which confront Pakistan and India as separate states Until now, they have been considered as a unit and there will undoubtedly be adjustments in present industrialization plans required by their separation India's problems stem from the backwardness of agricultural and primary industry techniques, and from the fact that the population is increasing at the rate of 5 million a year Thus, the contemplated trebling of the national income (envisaged by the Bombay Plan) would result in only a doubling of the income per capita by the end of the fifteen-year period

There has been considerable discussion in India on planned industrial development and a number of plans have been proposed The most widely publicized, and the most comprehensive, is the so-called Bombay Plan,

Tata's metal empire, represented by the iron and steel works at Jamshedpur (Bengal), largely accounts for India's current steel capacity of around 2 million net tons of ingots and castings.



Large Indian producers are Tata, Steel Corporation of Bengal and Mysore Iron and Steel Works. India's iron ore is ample but coal for both fuel and coking is poor. The country has vast chrome, vanadium and tungsten resources.

DATA ON INDUSTRY IN INDIA, 1939

	No of Establishments	*No of Workers*
Textiles	1,367	946,334
Engineering	1,024	253,248
Minerals and Metals	183	64,326
Food, Drink, Tobacco	3,035	264,418
Chemicals, dyes, etc	659	70,117
Paper and Printing	571	57,851
Stone, glass, woodworking	596	92,835
Leather and shoemaking	88	15,874
Gins and Presses	2,627	208,134
Miscellaneous	292	71,582
Total	10,442	2,026,919

formulated by a group of Indian industrialists in 1944 The Indian Federation of Labor also published a plan on similarly comprehensive lines, but with less detail and more ambitious targets Both of these plans were based on the idea of increasing the national income over a period of years at a pre-determined rate During the war official schemes for reconstruction and development over a five-year period . . covering agriculture, transport, education, and public health . . were drawn up by the Provinces and the Central Government Recently a report of the Advisory Planning Board of the Interim Government was published It was less specific than some earlier plans. The general targets, however, were of about the same magnitude as the Bombay Plan.

The industrialists' plan aims at trebling the national income of India within fifteen years, from an estimated 6.6 billion dollars to about 19.8 billion dollars, aiming at a doubling of per capita income and taking into account the rise in population mentioned above.

These increases in income are to be achieved by planned investment over the fifteen-year period and spread over the main groups of activities as follows.

CAPITAL INVESTMENT UNDER THE BOMBAY PLAN

(Millions of $)

Industry	13,463
Agriculture	3,727
Communications	2,825
Education	1,473
Health	1,352
Housing	6,612
Miscellaneous	601

The sources from which funds equal to 100 billion rupees are to be obtained are visualized by the authors of the plan as follows.

Hoarded wealth	3 per cent
Sterling securities	10 " "
Balance of trade	6 " "
Foreign borrowing	7 " "
Savings	40 " "
"Created money"	34 " "
	100 " "

According to the plan, investment and its effect upon the economy will increase as the fifteen-year period progresses In the first year of the plan, investment is set for 642 million dollars, and in the last year at 4.08 billion dollars

Although none of India's integrated long-term post-war plans are yet under way, new industrial developments based on short-term plans have been undertaken.

The textile industry, already one of the most important in India, is planning to increase its installed capacity by 30 per cent by 1951 It intends to raise the number of cotton spindles from the 1945 figure of 10,238,000 to 13,096,000 and the number of looms from 202,400 to 277,000.

The cotton division of the textile industry claims a leading position as the nation's largest business It employs 510,000 workers (with allied industries, the total is 727,112), compared with 314,000 workers in jute mills, 44,305 in wool mills, and 12,565 in silk mills. One hundred and twenty-five new cotton textile mills with a combined number of spindles totalling 2,744,000 are called for under industry's expansion program.

Although India's electricity has traditionally been obtained from coal, oil, and water-power, post-war development plans call for exploitation of the country's vast, untapped hydro-power resources. Before the war, per capita power production was only 5 kwh annually—compared with around 2,000 kwh in the United States. The hydro potential is estimated at 27,000,000 hp and expansion plans call for an investment of several hundred million dollars to increase power capacity by about 65 per cent. 12 new hydro-electric projects started since 1939 will be completed within the next 3 years, and 3 others have been approved by the government. Together, these will cost about 236 million dollars.

INDUSTRIAL PRODUCTION IN INDIA[1]

	Cotton Piece Goods (million yards)	*Cement (thousand tons)*	*Steel Ingots (thousand tons)*	*Pig Iron (thousand tons)*	*Coal (thousand tons)*	*(million kwh) Electricity (monthly average)*
1940/41	4,269 4	1,727	1,285 4	1,961 0	26,005	204
1941/42	4,493 4	2,247	1,363.1	2,015 0	24,463	214
1942/43	4,109 3	2,183	1,299 1	1,804 2	25,470	225
1943/44	4,870.6	2,112	1,365 5	1,686 4	22,483	227
1944/45	4,726 4	2,075	1,253 9	1,300 4	24,154	279

[1] United Nations, Dept of Economic Affairs, *Survey of Current Inflationary and Deflationary Tendencies*, September, 1947

The government has approved plans for the doubling of cement production by 1952, but it is questionable whether the target can be met Capacity of the industry in 1947 was estimated officially at 3 million tons, but production was only about ⅔rds of this figure Under the government plans, 19 new plants are to be erected and 15 of the old ones are to be expanded. Work is progressing on the construction of plant sites, and licenses have been granted for the import of 27 cement processing units from the United Kingdom, Denmark and the United States India is itself making parts for some units

Toward the end of 1947, economic activity in India was estimated to have fallen to a level a few points below that of 1939-40 At the wartime peak, it had exceeded the 1939 level by 18 per cent.

Iron and Steel production, 1946	
Pig iron	1,326,000 tons
Steel ingots and castings	1,229,000 tons
Coal production, 1946	26,370,000 tons
Textile production, 1946	
Cotton piece goods	4,009,000,000 yds
Cotton hand loom	1,300,000,000 yds
Kwh produced, 1946	3,484,000,000
Telephones, 1946	120,000

ITALY

Italy has made steady progress toward recovery in the first two years following the end of the war. But political difficulties with their effects on the morale of the people, which became intensified at the close of 1947, hampered seriously the rate of reconstruction achieved in 1947

In 1946 the level of industry in Italy reached only 25 per cent of 1938 By the middle of the year 1947 it had risen to 70 per cent of 1938 but a number of unfavorable circumstances, such as the scanty supply of raw materials, electric power, and coal, then began to retard recovery.

1945 marked the depth of the depression for Italian agriculture Production was reduced to 64 per cent of the 1938 level. This rose to 80 per cent in 1946, but in 1947 agriculture again declined as a result of scarcities of fertilizer, machinery, and the loss of livestock.

The Italian economic situation is characterized by a serious imbalance between the population, which is rapidly increasing, and inadequate natural resources and capital investments. A higher standard of living for the Italian people depends upon the solution of the problems of emigration and increase of production, accumulation of foreign capital, and the redistribution of savings.

At present, Italian economic life is conditioned by the State in a great variety of ways. These range from direct or indirect concessions granted to private enterprise in many forms to participation by the State in private business, and to direct government operation of public services and business concerns.

In the field of transport and communications, the railways, posts and telegraph, and interurban telephone services are run by government. The government is a shareholder in radio, telephone, air and sea navigation companies Government, through the Instituto per la Riconstruzione Industriale, controls 23 per cent of electric power production, and another 7 per cent is state-owned The A C.A I (Italian coal company), whose capital was largely subscribed by the government, produces almost all the coal mined in Italy 80 per cent of the steel industry was controlled by the Finsider Holding Co , and 90 per cent of the shipyards by the I R.I. Social insurances are managed by public corporations, and the I N A. (National Life Insurance Institute) occupies a pre-eminent place in the field of private insurance. In banking, 34 per cent of all savings were held directly by the state (at the end of 1946), 39 per cent by public or state-controlled institutes, 9 per cent by cooperative banks, and only 18 per cent by private banks.

Under these conditions, it is regarded as essential that the government take the initiative and draw up an economic plan for Italy designed to meet international commitments and raise the standard of living of the people. Such a plan is being prepared by the National Economic Council. The first and most difficult task has been the collection of information and appraisal of the status of various segments in the national economy.

Industrial capacity was not seriously reduced by war damage. Only establishments located in central and southern Italy suffered extensively. Most of the equipment in northern Italy emerged from the war unscathed, so that it has been estimated that 80 per cent of the country's 1942 capacity was intact at the end of the war.

Power plants in central and southern Italy suffered a loss of about 50 per cent of capacity. This has been replaced in part by supplies moved from northern areas. The damaged high-tension network has already been repaired. Electrical production for the country in 1947, which is estimated to be 20.6 million kwh, is about 20 per cent above the 1939 level.

The pig-iron industry suffered severe damage, causing almost a 70 per cent reduction in capacity. The steel industry suffered only about 20 per cent loss of capacity, but the loss consisted mainly of electric-furnace equipment removed by the Germans. As a result, only coal furnaces remained. With the extreme scarcity of coal, the effect on production was out of proportion to the capacity lost. With heavy emphasis being placed on electro-furnace reconstruction, steel output in the first half of 1947 rose steadily. The full year's output was expected to approach 2 million metric tons, with 1948 production scheduled to reach 2.5 millions – a figure nearly 10 per cent above the 1938 level.

The engineering industries, which are mostly centered in the north (80 per cent in the Po valley), suffered little damage. Many of these have attained between 60 per cent and 70 per cent of the pre-war level. The electro-mechanical industry is working at a rate which is only retarded by shortages of raw materials.

The severe damage to shipyards has made it unlikely that they will regain the pre-war level for some time.

The textile industry was not seriously affected by the war. Shortages of materials, however, have retarded recovery. UNRRA cotton, spun for UNRRA account, assisted in raising production. The United States provided a 25 million dollar cotton loan to purchase additional equipment and materials so that Italy might earn funds by export. Barter agreements with Egypt and Palestine made additional cotton available. While production in 1946 barely exceeded half the 1938 level, the trend has continued upward. The natural silk industry, which before the war was of considerable importance, has been largely superseded by expanded rayon and other synthetic fiber production. Lack of coal and sulphuric acid, however, is keeping production at a low level.

Italian transport was heavily damaged by the war. About 35 per cent of the steam locomotives and 45 per cent of the freight cars were lost. The merchant marine was decimated, and cannot be restored to the pre-war level for some years.

Italy has been making desperate efforts to export, and has actually succeeded in nearly balancing its imports and exports if trade with the United States is excepted. With the U. S., however, the country has a serious debit balance.

Italy's cash requirements for reconstruction were estimated in 1946 to be 4 billion dollars over a four-year period. Although such a vast amount of aid cannot be expected to materialize, considerable sums have become available to the government and more will be provided under the Marshall Plan.

Since the middle of 1945, Italy has obtained the equivalent of 462 million dollars from hard-currency countries. Early in 1947, the Export-Import Bank granted a 100 million dollar credit, which by the end of the year had been almost completely earmarked for industrial reconstruction. In August, 1947, 23 million dollars was allocated to Fiat, Montecatini, and Pirelli. In October, 5.8 million dollars was spent on shipyard facilities. In the same month 32 million dollars was earmarked for equipment destined for 60 medium and small firms in the chemical, rubber, electro-mechanical, and metallurgical industries. Finally, 14.2 million dollars was allotted to the five leading steel mills, and 22.3 million dollars to another group of medium-sized chemical and metallurgical firms.

The following list summarizes the foreign credits Italy had arranged by the middle of 1947.

MID-1947 CREDITS GRANTED ITALY

U. S. Surplus Property Credit	$160 million
U. S. Maritime Commission Credit	37 "
Export-Import Bank of Washington	130 "
Argentine Government	122 "
French Government*	3 "
Danish Government*	5 "
Belgium Government*	9 "
Netherlands Government*	1 "

* In connection with payment agreements

The future course of the Italian economy will depend heavily upon the amount of assistance made available through the European Recovery Program. On its own, the Italian government submitted proposals to the Committee for European Economic Cooperation outlining a course of reconstruction for the nation. General scaling down of the probable funds to be made available by the United States will undoubtedly make full realization of these targets impossible.

The estimates for agriculture, 1947-48 to 1950-51, are based upon logical expectations of climatic conditions, raw material and mechanical supplies. They also consider plans for irrigation and reclamation which have been approved by the government. The area to be sown to wheat, and the anticipated subsequent production, are somewhat below the 1934-38 level (when efforts toward self-sufficiency were being pursued) but estimates for other crops are higher. The end effect—the level of consumption—would be lower than the 1934-38 period.

The total output of electric power is projected as follows.

Year	*Millions of kwh*
1947	20,600
1948	23,510
1949	26,380
1950	28,710
1951	31,260

These estimates leave no power surplus for export, but considerable export margins are foreseen for the output of Italian industries manufacturing parts for the electrical field as estimated at 15 million dollars in 1947 and 33 million dollars in 1951

Kwh produced, 1946-47 (Sept.-Aug.)	17,576,000,000
During the first eight months of 1947, production was at the rate of 20,676 million kwh annually	
Iron and Steel production, July-June, 1946-47	
Steel ingots and castings	1,469,000 metric tons
Pig iron	268 000 " "

In the case of coal, Italian needs, home production, and the deficit to be met by imports are calculated as follows (in thousands of metric tons)

Year	*Total Demand*	*Italian Output*	*Imports*
1947	12,430	1,800	10,620
1948	16,626	2,223	14,400
1949	18,365	2,765	15,600
1950	20,300	3,300	17,000
1951	22,500	3,300	19,200

In view of the probable continuation of a worldwide shortage of coal, these figures are undoubtedly optimistic The country's total demand for liquid fuels is expected to rise from 4.4 million metric tons in 1947 (at a cost of 85 million dollars) to 6.3 million metric tons in 1951 (estimated to cost 115 million dollars)

Since the Italian steel industry has been, and will continue to be, heavily dependent upon foreign coal and iron, expansion is planned at a conservative rate Estimates place Italian steel requirements at 3.2 million metric tons in 1948 and at 4.3 million metric tons in 1951. Domestic output should provide not less than 2.5 million tons in 1948 and 3 million tons in 1951

The reconstruction of the Italian merchant marine will increase its capacity from 2.4 million deadweight tons in 1947 to 3.2 million in 1951 Construction in Italian yards is estimated to reach 230 thousand tons in 1949, 259 thousand in 1950, and 318 thousand in 1951.

RELATIVE IMPORTANCE OF INDUSTRY BY NUMBER OF EMPLOYEES[1]

	Per Cent
Textiles	14.5
Mechanical Engineering	14.4
Building	11.0
Food Processing	10.3
Stone, Clay, etc	4.1
Mines and Quarries	3.1
Timber	2.3
Chemicals	2.3
Other Industry	41.1
Total Industry	74.4
Handicraft	25.6
Grand Total	100.0

[1] UNRRA Mission Report on Italy, 1947

NUMBER OF INDUSTRIAL ESTABLISHMENTS, 1937-39

Size of Plants	*No of Establishments*	*Employees*
Employing 2 to 10 workers	278,865	879,512
Employing 11 to 50 workers	25,376	569,561
Employing 51 or more workers	10,107	1,172,422
Total	314,348	2,621,495

1947 INDICES OF INDUSTRIAL PRODUCTION

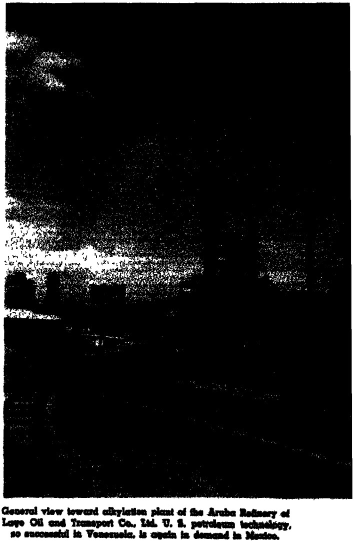
(1938 = 100)

Textiles[1]	58
Mining[1]	47
Metal industries[2]	70
Building materials[2]	50
Electrical industry[2]	122
Chemical industry[1]	70
General Index[2]	68

[1] January, 1947

[2] June, 1947

[3] Unofficial estimate, June, 1947



General view toward alkylation plant of the Aruba Refinery of Lago Oil and Transport Co., Ltd. U. S. petroleum technology, so successful in Venezuela, is again in demand in Mexico.

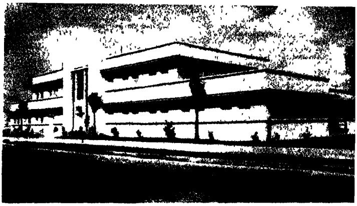
MEXICO

Since 1940 hundreds of new plants have sprung up throughout Mexico Today's problem involves not only maintaining these new industries, but in further pursuing the plans formulated in 1944 for the country's overall plan of industrialization In 1946, Mexico passed an industrial law defining the *new* and *necessary* industries and providing financial incentives for industries essential to the basic economy of the nation The United States and Mexico have cooperated closely for the long-range development of the latter's primary industries United States capital has increasingly been moving south of the Rio Grande despite the idea long prevalent among United States businessmen that the country possesses an unhealthy climate for foreign business investment

Mexico's economy is still predominantly agricultural, with about 65 per cent of the total population engaged in agricultural pastoral activities The most significant development, which has directly stimulated industrial growth, is the attention which is being paid by the government to the expansion and improvement of irrigated farms Approximately 4 million acres are under new irrigation, with about 2,800,000 of this total placed under irrigation since 1940 An adequate supply of foodstuffs is indispensable to any program of industrialization Mexico recognizes this in the federal allocations which are being assigned to irrigation and hydro developments During the last years of World War II the Banco Nacional de Credito Ejidal, S A., ordered well over 32 million dollars worth of agricultural machinery to be utilized in its agricultural program Closely associated with the irrigation projects will be the expansion of electric power facilities which will in part compensate for the scarcity of high-grade coal

Mexico's program of industrialization stems from her 1939 *Ley de Industrias de Transformacion* passed to encourage the establishment of new idustries New plants and companies receive favorable concessions and certain exemptions from import duties on new machinery and raw materials A benevolent attitude was also adapted regarding federal, excess profits, and stamp taxes Many of the new companies which sprang up in and after 1940 operated for a market where any significant volume or variety of products from the United States or Europe could not be imported For the large part, they lacked any local competition However, they did acquire certain technological skills which are now proving advantageous in lowering prices and improving the quality of Mexican products.

In 1944 Mexico defined a long-term program of industrialization which, over a period of 10 years, would expand the iron-steel industry, modernize the textile industry, increase power facilities through an expenditure of 50 million dollars, expand the irrigation system at a cost of 158 million dollars, rehabilitate the railroad system, make the country self-sufficient in cement and establish the beginning of a much needed chemical industry. There have been a number of cutbacks in the original plans of the Mexican-American Industrial Commission which fostered this systematic development of various industries. However, a large share of the 383 million dollars which was allocated has already been spent in the



Air conditioned buildings of new E. R. Squibb & Sons plant for the manufacture of penicillin and other medicinal products.

Steel girder will carry siphon pipes for the tremendous Valsequillo irrigation project. Handled by efficient Mexican National Irrigation Commission it will reclaim 80,000 acres.

Three mill buildings of newly constructed Laminadora de Acero. They will house ingot furnaces, blooming and structural shapes mill, as well as shears and transfer tables.

United States for the purchase of the industrial and construction machinery required by the program

About 35 per cent of the country's industrial production is centered in or around the Federal district The principal manufacturing industries and the percentage each contributed to the total national production in 1944 is as follows.

Cotton textiles	29 per cent
Wheat mills	12 " "
Breweries	10 " "
Soap	6 " "
Vegetable oils	6 " "
Tobacco	6 " "
Iron and steel	5 " "
Rayon textiles	4 " "

Modernization in industry is a foremost objective in improving the productive capacity of the majority of Mexican plants This may be illustrated in the textile industry where the Mexican weaver operates 4 looms as compared to 30 looms per operator in England and 100 looms per operator in the United States

Mexico City has experienced a phenomenal growth in recent years. Profitable commercial and manufacturing investments during the war years provided investors with excess capital which has been used for real estate development. Since 1940 there have been over 4,000 building permits issued annually, with construction expenditures for industrial and home buildings estimated at about 40 million dollars in 1947.

The Federal District, which represents about 34 per cent of the country's industrial production, faces growing competition from the northern cities of Monterrey, Saltillo and Durango. The Federal District, however, still occupies first place in industrial importance, followed by Veracruz, Nuevo Leon, Puebla, Coahuila and Jalisco

Electric power, as in any other country with a program of industrialization, is receiving particular government attention, with present hydroelectric power estimated at only 440,000 kwa The undeveloped potential of the country is estimated at over 7,000,000 kw. Since 1937, when the Federal Electricity Commission was created, 28 generating plants have been built. The largest is the Ixtapantongo station which will eventually have a capacity of 85,000 kw It is expected that by 1949 a total of 327,340 kw in new capacity will be added to the present 440,000 kw

Ixtapantongo, 100 miles northwest of Mexico City, will double power for rapidly industrializing central highlands.

Mining continues to exercise an enormous influence on the country's economy Although only 6 per cent of the population is engaged in mining, it accounts for 17 per cent of total value of production The Index of Production reached a new high of 104 during war years (1937=100) and dropped to a low of 72 in 1946

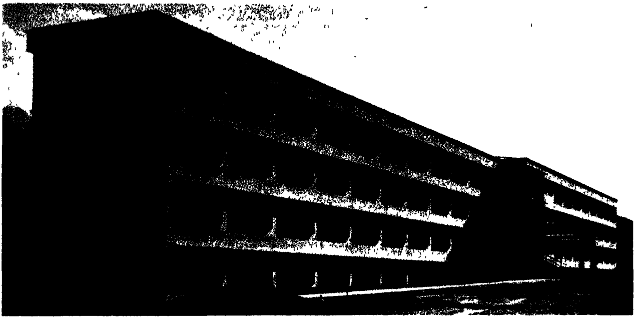
President Aleman's visit to the United States in 1947 aimed to enlist the assistance of American government and private capital for the further industrialization of Mexico Mexican law now specifies that the controlling share in any business be Mexican, a regulation that may sometimes be waived in the country's interests The bulk of foreign investment in Mexico today is United States capital Profits on manufacturing investments have been exceptionally high in recent years, reaching an average of 18 per cent Various statements in the press seem to indicate that the present administration is principally interested in accelerating the program of industrialization and that it does not particularly care whether needed industrial plants are built with public or private, foreign or national money

The Mexican Federal Budget for 1948 amounts to 475 million dollars and is the biggest in the history of the country The Government plans to obtain 410 million by regular taxation and the rest by the sale of bonds; 50 million of which will be road bonds, 7 4 million for electrification and 4 million for ports.

THE BUDGET IS DIVIDED AS FOLLOWS

Legislature	$ 3 1	million
Executive Office	0 35	"
Juridical	1 5	"
Interior	2 6	"
Foreign Relations	5 3	"
Treasury	41.	"
National Defense	49.5	"
Agriculture	3.5	"
Communications and Public Works	85 5	"
National Economy	95.	"
Public Education	50.	"
Public Health	24.	"
Navy	14.5	"
Labor	1.1	"
Agrarian	2.7	"
Hydraulic Resources	48.5	"
Federal Attorney's Office	0.8	"
National Monuments	1.3	"
Military Industry	3.5	"
Investments	19.5	"
Additional Expenditures	47.5	"
Public Debt	72.5	"

The biggest item is that assigned to the Department of Communications and Public Works, which this year has a budget of 86 million dollars as against 6 million in 1947. Of the amount allotted to this Department, 56



This is one of the several buildings comprising the Instituto Tecnologico y de Estudios Superiores in Monterrey. It was planned by businessmen who recognized the need for skilled workmen and engineers for plants in northern Mexico. It will cost 5 million dollars.

million will be spent on roads, construction, conservation, etc

In the amount assigned to the Department of Economy the 6 2 million dollars that the National Commission of Electricity will spend on electrification are included

The Federal District's Budget for 1948 amounts to 35 million dollars In 1947 the Federal District had a budget of 31 million dollars

With an increase in industrial production of more than 50 per cent during the last seven years, and an immeasurably improved standard of living, the country occupies a strong position to continue its industrial development. Inflation continues to threaten the security of new developments Despite the shortage of equipment and construction equipment, over 400 new projects have been undertaken, including the important new steel plant of Altos Hornos de Mexico, Celanese Mexicana, Viscosa Mexicana, Compania Industrial de Atenquique, Compania Electrica de Mexico, "Mexican Fertilizers," Cobres de Mexico and some sugar mills. Cananea Copper (a subsidiary of Anaconda) has recently invested another 12 million dollars in enlarging its present refinery and the Mexican Monterrey Steel Works has doubled its prewar capacity International Harvester, Westinghouse, Crosley, Johnson & Johnson, Goodyear, and Worthington Pump and Machinery Corp are only a few of the United States companies which are establishing, or studying the possibilities for developing, plants in Mexico.

INDUSTRIAL CENSUS OF MEXICO FOR 1944[1]

	Number of Establishments	*Personnel*	*Salaries Paid*	*Capital Invested*	*Value of Production*
			(In 1000's of U.S. Dollars)		
Textiles .	2,499	105,810	41,471	82,899	197,260
Foundries and Metallurgical Industries	4,871	40,084	16,794	30,224	59,924
Wearing Apparel and Toilet Preparations	6,372	28,717	9,675	15,519	35,537
Food Products	8,169	73,283	25,346	59,537	10,539
Wood and Furniture	4,765	30,606	9,391	16,143	34,349
Glass and Porcelain	146	7,490	3,570	6,971	12,557
Hides and Leather	1,174	6,628	2,437	5,811	16,765
Electrical Appliances	229	927	342	619	1,111
Chemicals and Pharmaceuticals	444	14,049	8,297	28,934	42,458
Vegetable Oils, Paints and Varnishes	212	1,513	578	1,255	3,348
Rubber	176	2,141	915	5,148	17,613
Soap	34	3,920	1,905	6,374	19,738
Paper and Paper Products	168	6,722	3,068	10,266	21,218
Graphic Arts	1,830	13,875	6,875	10,564	20,204
Tobacco	74	3,670	1,570	12,860	14,460
Jewelry	678	1,394	482	794	1,518
Optics	31	175	93	305	441

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[1] Compendio de Estadistica, 1947: Secretaria de la Economia Nacional, Mexico, D. F.

German autos are in production at Ruesselheim where the General Motors owned Opel plant manufactures a four-cylinder motor.

THE NETHERLANDS

The Netherlands' economy was seriously affected by the war in two ways. Physical damage to industry, agriculture, and transport, and disruption of the close economic ties with German industry.

Material damage has been officially estimated at 6.3 billion dollars. Nearly 500,000 acres of farm land were inundated, and it is believed that production on the reclaimed land will not reach pre-war levels for at least five years. At least 200,000 acres were flooded with salt water. Dutch railroads were practically demolished, and the important ports of Amsterdam and Rotterdam were seriously damaged. The Dutch merchant marine lost more than 40 per cent of its pre-war tonnage of 2,800,000 gross tons.

Destruction of dwellings was particularly acute over 350,000 were slightly damaged, 43,000 were severely damaged, and about 92,000 homes were destroyed.

Considerable progress has been made in overcoming most of the direct consequences of the war. Much of the flooded areas have been returned to cultivation, although the productivity of land flooded with salt water remains low. Mine-fields have been cleared, transport restored, and nearly all bridges repaired. The railroads are carrying more passengers and goods than before the war. Road repairs are progressing rapidly. Shipping has reached 85 per cent of pre-war. By the middle of 1947, the level of industrial production had climbed to 94 per cent of pre-war.

Although The Netherlands has traditionally been a creditor nation on international account, the loss of

Steam turbine units for generating current for transmission to the oil wells in Lake Maracaibo. Once the power leaves the outdoor substation, the distributing system is entirely over water.

Italy's reconstruction is exemplified by the speed with which the automotive and railway industry is beginning to produce in volume.

German trade and difficulties in the Netherlands East Indies have combined with the requirements of capital reconstruction to place a heavy drain on finances As a result, overseas assets — estimated at about 600 million dollars — are being liquidated and credits have been obtained to assist reconstruction

Since the end of war in 1945, The Netherlands has obtained the equivalent of 898 million dollars in credits from the following sources:

POST-WAR CREDITS

U S Surplus Property Credit	$ 30	million
U S Lend-Lease credit	48	"
Export-Import Bank of Washington	205	"
U S Commercial Bank credit	93	"
U S private bond issue	20	"
Canadian Government credit	125	"
Swedish Government credit	28	"
Swiss Government credit	21	"
International Bank loan	195	"
British Surplus Property credit	8	"
Belgium Government credit	69	"
French Government credit	2	"
Swedish Government (short-term loan)	4	"
United Kingdom credit[1]	50	"

[1] As a result of monetary and payments agreement

The chief factors limiting industrial recovery are twofold First, the scarcity of raw materials and fuel, which has limited output in almost every field of economic activity Lack of fertilizer has seriously retarded the restoration of agricultural productivity Second, the loss of the German market which before the war was so important to the Netherlands' economy Dutch industry has long been geared to the use of German raw materials and semi-manufactured products, and a large part of its industrial equipment is of German origin and must rely upon German industry for replacement In addition, Germany was a principal customer of the Rhine fleet, and German goods moved through Dutch seaports The Anglo-American Zone of Germany has recently taken steps to alleviate this situation. Among other measures, trade agreements have been signed between The Netherlands and the U S-U K. Zone, and at least a million tons of German exports are slated to move through Dutch ports to overseas destinations

THE NETHERLANDS' STATISTICS

No of People Employed (1st Quarter, 1947)	694,610
No of Industrial Workers (June, 1947)	599,600
Total Number of Industrial Establishments	9,788
Average Annual Income of Industrial Workmen (U S Cy)	$8-900
Total Capital Invested in All Industry (U S Cy)	$28 billion
Railroads, miles, 1947	2,020
Highways, miles, 1947	1,566

Another obstacle to recovery has been the disturbed conditions in the Netherlands Indies At least 1/6 of pre-war trade was with the Indies.

Netherlands' reconstruction has been planned to only a limited degree No specific production goals have been set The government, however, has indicated that industrialization will proceed along two general lines. One includes the production of more capital equipment, for which there will apparently be a considerable world demand for many years The second involves increased output of high-quality consumer goods The program is being assisted by a research effort to determine what types of capital equipment and consumer goods can be most efficiently produced by The Netherlands' economy. For the most part, further industrialization of The Netherlands will be in the hands of private enterprise Government's role is chiefly that of sanctioning new developments and assisting the execution of plans.

Mechanization of agriculture is high on the list of Dutch post-war projects New machinery is being obtained, particularly tractors and tractor-drawn implements The size of the average farm is being increased through a government-sponsored re-allocation of land between farmers and the relocation of farmers in new areas of production The government is also fostering the cooperative use of farm machinery, since the individual farmer is generally unable to afford modern equipment

The Dutch Central Planning Office has made a forecast of the balance of payments for the period 1947-52 In making these estimates, many uncertainties have been admitted, so that they should be regarded only as a

STATISTICS ON SELECTED INDUSTRIES

	No of Establishments	*No of Employed*	*Value of Exports*[1]	*Value of Imports*[1]
			(Millions of $)	
Chemical and Allied Industries	401	39,255	49 8	110 3
Cement Mills and Rock Product Industries	625	32,834	3 9	22.5
Food Processing Industries	1,489	85,816	79.6	68.2
Metallurgical and Metal Working Industries	101	17,767	94 5	354 6
Electric Power Generation	178	—[2]	—[2]	—[2]
Pulp and Paper Industries	219	17,270	11.9	19.5
Textiles	578	74,427	60 6	65 8
Others	6,375	—[2]	154.4	503.2

[1] Jan.-Sept., 1947 [2] Not available.

rough guide to the future. These plans envisage a deficit on international account until 1950, with favorable balances of rising magnitude thereafter. Income from shipping, for instance, is scheduled to rise more than threefold above 1938 by the end of 1948, and to continue at that level. Exports are to follow a generally rising curve, doubling between 1947 and 1948, and increasing an additional 50 per cent more by 1952. Imports, which today are at a high level, are due to rise about 40 per cent by 1950.

During the next few years no income is expected from the capital invested in the Indies before the war, due to the reconstruction effort still required there. Trade with the Indies is gradually getting under way, having until recently been almost entirely halted.

A clue to the pattern of Dutch reconstruction may be gained from the allocation of funds obtained from the International Bank for Reconstruction and Development. The 195 million dollar credit will be expended as follows: machinery and tools, with a small part for steelworkers' housing, 93 million dollars; transportation and commerce (trucks, shipyard and railway equipment), 56.5 million dollars—of which 45 million dollars will be for purchase of U. S. ships, agricultural projects, chiefly machinery, 29 million dollars, and public works projects (timber, steel, and cement), 16.5 million dollars.

NORWAY

For centuries Norway has been heavily dependent upon the outside world. With heavy export surpluses in some fields of production, it has placed equally heavy reliance upon compensating imports. There are large export surpluses from the fishing and whaling industries, paper and pulp, certain ores and minerals, and in a limited degree from the electro-chemical and electrometallurgical industries. Besides, shipping services to the rest of the world play a crucial role in Norwegian economy. The merchant fleet before the war was the world's fourth largest, and Norway's merchant tonnage was much larger per capita than that of any other country. Only about 15 per cent of its tonnage, which amounted to about five million tons, was engaged in transport services for the home country, the rest was engaged in carrying the goods of other nations.

In other fields, Norway had a considerable deficit, requiring imports of machinery and equipment of many kinds, oil, coal, iron and steel products, chemicals and other raw materials. Norway also imported about 80 per cent of the cereals required for human consumption and much of the fodder needed for farm animals. It imported phosphates and potash fertilizers.

The pre-war balance of trade showed a constant deficit which was made up by "invisible" exports, chiefly shipping services. Sweden, the United Kingdom, and Germany were Norway's leading trade partners. Between them they supplied 46 per cent of imports and took 49 per cent of exports in 1938.

The Norwegian economy suffered severe dislocations as a result of the German occupation. The country was isolated from its normal foreign suppliers and an effort was made to orient the economy to a German-dominated Europe. Economic activity was maintained at a high level, but productivity decreased in all fields.

Some Norwegian industrial installations were destroyed during the war by sabotage and by Allied bombings. Some were destroyed during the German invasion, and most of the northern industries (chiefly fish conserving plants) were wrecked before the German withdrawal in 1944. Although Norway cannot be said to have lost heavily from destruction, the total depreciation of industrial plants in the war years is estimated at 35 per cent. Coupled with losses of livestock, personal effects, communications, and other assets, the total cost has been set at about 1.333 billion dollars of the 1939 value.

Norway lost more than half its ship tonnage during the war. In 1939 the merchant fleet amounted to 4,846,000 gross tons. In May, 1945, the fleet had only 2,727,000 tons. Toward the end of 1947, newly built or acquired tonnage raised the total to 3,700,000 tons. At least 2 million tons more are under construction or on order in Norwegian yards, in Sweden, Denmark, and the United Kingdom. By 1950 the fleet is expected to reach or pass its pre-war level.

Industrial production in Norway has recovered rapidly, reaching the 1938 level of activity in the spring of 1946. However, the present economy is beset with problems arising from a shortage of manpower, particularly skilled workers, and an inability to obtain adequate supplies of imported goods, both manufactured and primary products. The general goal for country, as set forth by the government, is to raise the national income to the pre-war level by 1950. Large capital investments will be required to compensate for war losses. An official estimate of the amount and distribution of investments to be made by 1950 follows, based upon the value of the crown in 1939. Conversions to dollars are made in the following table according to the exchange value of 4.3 crowns to the dollars.

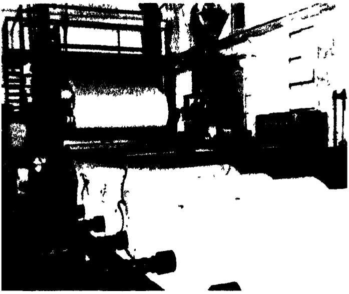
Merchant shipping	$200	million
Whaling	17.5	"
Land transport	46	"
Fishing boats and equipment	30	"
Construction and machinery in manufacturing industries	115	"
Stockpiling for industry	90	"
Stockpiling for distribution.	75	"
Increasing agricultural stocks	30	"

Detailed industrial development plans have not been formulated, but a further increase in industrial capacity is generally planned where new undertakings can be established on a sound economic basis. Most of the planning for new industries remains in private hands, but the government can influence development by (a) supervision of import licenses; (b) rationing of building materials; and (c) granting of federal loans and guarantees to new industries requiring such assistance. The government has the power to control investment, but has so far restricted its use to directing investment to projects of an essential and non-duplicating nature. The most important industrial developments planned to date include:

(a) An iron and steel mill, which will be based on domestic ore and electricity, and which is planned to cover most of the country's needs for iron and steel products At present, all such goods must be imported. The new mill is being financed by the Norwegian government but will operate as a commercial corporation.

(b) A large aluminum plant, started during the war, is being completed in western Norway

(c) The capacity of Norwegian shipyards is being expanded to reduce the country's reliance upon foreign builders This expansion will not completely satisfy the country's needs, however Government assistance will be extended to finance the new yards.



Paper mill of the Borregaard Corporation at Sarsborg, Norway. Foreigners are not permitted to hold shares in this concern which also owns paper mills in Austria, England and Sweden.

Power station of the Norsk Hydro Corporation's chain on the Skien River. One of 54 hydro plants along river, it produces 28,000 kw for chemical and metallurgical industries.

(d) The spinning capacity of the Norwegian textile industry is being expanded to enable the spinning section to more nearly meet the needs of the weaving mills At present a large part of the industry's yarn requirements are imported.

Hydro-electric power will also be further developed to support the expanded needs of industry and home consumers

Norway is unable to meet all of the demands for capital from its own resources and will depend upon foreign loans to achieve the goal set for 1950 But the country is considered a good risk, and has already obtained large credits from abroad and is less concerned with its adverse balance of payments than most other European countries.

Foreign trade has been resumed on a wide pattern, chiefly through bilateral agreements with European countries In 1946 Norwegian imports were valued at 392 million dollars, and exports at 242 million dollars At about mid-year the value of 1947 imports was officially estimated at 494 million, and exports at 315 million dollars

Norway obtained a 50 million dollar loan from the Export-Import Bank, of which less than 10 million dollars had been expended by the end of 1947. Other credits obtained by Norway included 10 million dollars from the U S for the purchase of war surpluses, 16 million dollars from the Maritime Commission to buy ships; 16 million dollars from commercial banks in the U S.; and a private bond issue of 10 million dollars floated in the United States The Canadian government granted a credit of 30 million dollars, still only partly used The Netherlands, Switzerland, and Sweden have also supplied funds to Norway The Swedish credit is valued at about 80 million dollars

NORWEGIAN STATISTICS
1947

Number of people employed in industry[1], 1945		280,000
Kwh produced[2]		9,852,000,000
Trade, 1946		
Imports		$393,000,000
Exports		$242,000,000
Industrial Production, May, 1946·		
(Index: 1938 = 100)	1945	1946[3]
General Index .	69	104
Export Industries	45	68
Mining and Electro-metallurgy	20	50
Chemical and Electro-chemicals	77	99
Paper and Pulp	38	63
Mechanical and Metallurgical	102	149

[1] Includes mining and construction

[2] Powerhouses with capacity of more than 1,000 Kw, and including production of establishments generating their own power.

[3] Latest month, May.

SOVIET UNION

War Damage to the Soviet Union was officially set at more than 128 billion dollars Dollar value is actually of little importance in evaluating the significance of war destruction in the Soviet Union The rate of Soviet economic recovery and development must be measured against the physical losses sustained during the war and the long occupation of productive industrial and farming areas by Germany.

More than 1,700 cities and 70,000 villages and hamlets were partially or completely destroyed Six million buildings were razed, depriving 25 million persons of a place to live The major industrial centers of Stalingrad, Leningrad, Sevastopol, Kiev, Minsk, Odessa, Smolensk, Novgorod, Pskov, Orel, Kharkov, Rostov, and Vornezh were wrecked. Some of them, like Stalingrad, were almost completely leveled About 31,000 industrial enterprises were damaged or destroyed It has been estimated that the Germans wrecked or removed 239,000 electric motors and 175,000 lathes Sixty large power stations, which produced 5 million kwh annually before the war, were wrecked

Communications in the area held by Germany were virtually eliminated It has been claimed that more than 40,000 miles of railroad right of way were wrecked The Germans used a machine to rip up ties and rails as they retreated Some 4,100 stations, 36,000 telegraph offices, telephone exchanges and other communication facilities were destroyed 50,000 miles of roads were blasted by mines and 90,000 bridges, large and small, were removed or damaged Farmers lost 7 million horses, 17 million head of cattle, 20 million hogs, 27 million sheep and goats, and over 100 million farm fowl.

These figures do not include the loss of manpower, which has been variously estimated at between 3 and 7 million (not counting civilian deaths and the effect of a lowered birth rate on the population) Soviet industry and workers emerged from the war much weakened

Reconstruction followed the retreating Germany army, but at the end of the war the immensity of the task had only been partially begun. Consequently, the Fourth Five-Year Plan has been outlined "for the *restoration* and development of the national economy, 1946-50."

The aim of the plan is to bring agriculture and industry to the pre-war level by about 1949 and then to surpass it by a substantial margin Output in 1950 is to be 48 per cent above the 1940 level. This will mean restoring the industry of devastated areas to or near the pre-war level and continuing the expansion of production in the Urals, the Kuznetsk area, and on the Volga.

The present plan replaces the Fifteen-Year Plan, which was being prepared when the war in Europe diverted all Soviet resources to war production Long-term goals, now set for 1960, have been specified by Soviet planners as follows: 50 million tons of pig iron; 60 million tons of steel; 500 million tons of coal; and up to 60 million tons of oil.

The major goals of the present plan are given in the following table:

PRODUCTION PLAN FOR 1950

Item	*Unit*	*Volume*
Pig iron	million metric tons	19.5
Steel	million metric tons	25 4
Machinery and steel manufactures	billion 1926-7 rubles	97.0
Coal	million metric tons	250 0
Petroleum	million metric tons	35 4
Aluminum	thousand metric tons	100
Copper	thousand metric tons	266
Autos and trucks	thousands	500
Tractors	thousands	112
Paper	thousand metric tons	1,340
Cotton (raw)	million metric tons	3 1

Source State Planning Commission

More detailed figures on the 1950 goals for Soviet industry and pre-war production are included in one of the tables below

At the end of the first year of the Fourth Five-Year Plan, it was announced that targets had been reached and surpassed in some branches of industry, but that several critical sectors had fallen short of the goal

Heavy industry in general, and chemicals, textiles, and coal and oil production surpassed the goals The worst showing was made by agricultural machine building plants and transport equipment producers

Toward the end of 1947 it was apparent that excellent harvests, an increase in foreign trade, the movement of reparations from Germany, and better organization of the reconstruction effort were contributing to a rapid achievement of goals It has been reported that the famous slogan of the first Five-Year Plan, "Five Years in Four," may be revived in an attempt to complete the present plan by 1949, instead of 1950.

Some measure of the progress achieved in 1946 may be gained from official reports that six blast furnaces, 18 open-hearth furnaces, nine rolling mills, one blooming mill, 11 coking batteries, and 117 power station turbines (including two of 100,000 kva capacity) were built, or restored, and put into production. The White Sea-Baltic Canal was reopened to traffic Some 300,000 spindles were added to textile mills Daily capacity of sugar mills was raised 10,000 tons. With rapid demobilization, 3 million workers were added to employment rolls.

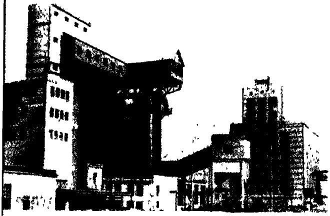
In 1947 the country reached and passed the 166 million ton level of coal production which was set in 1940. Steel production is scheduled to increase by nearly 3 million tons, and pig iron by more than 2 million tons. New power stations will add 2,000,000 kva capacity.

Expansion of consumer goods production and good harvests resulted in a lowering of retail prices several times during 1947, and rationing was abandoned by the end of the year. An indication of the favorable food position was provided by a doubling of the amount of grain to be supplied to Czechoslovakia under a bilateral agreement (from 200,000 to 400,000 tons) and the agreement to supply the United Kingdom with 750,000 tons of cattle feed. The Czechs also obtained 200,000 tons of cattle feed.

Following the defeat of Germany in 1945, the Soviet

A new coking battery of the Kemerovo coke and chemical plant in the Kuznetsk coal basin.

Construction of the first group of new gas holders for the Saratov works in process of completion near Moscow.

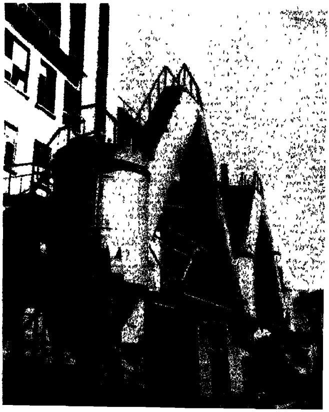


Restored soda works in Slavyansk, Stalino Region. The plant was seriously destroyed by the German invaders.

Plant for extracting oil from shale for production of gas for Leningrad, an enterprise developed under fourth of five-year plans.

Women are employed for reconstructing Petrovsky Iron and Steel Plant in Dnieperpetrovsk, Ukraine.

Sulphuric acid department of the large Aktyubinsk Chemical Works utilises locally produced phosphorite.



STATISTICS ON THE SOVIET UNION
GOALS OF THE FOURTH FIVE-YEAR PLAN, 1947-50

(All tons are metric)

	1950	*Latest Reported Production* 1940
Iron (tons)	19,500,000	14,900,000
Steel (tons)	25,400,000	18,400,000
Rolled steel (tons)	17,800,000	12,800,000
Coal (tons)	250,000,000	164,600,000
Oil (tons)	35,400,000	34,300,000 tons[1]
Gas (from coal and shale) (cu ft)	67,096,600,000	
Natural gas (cu ft)	296,637,600,000	
Electric energy (kwh)	82,000,000,000	47,000,000,000[2]
Locomotives, trunkline	2,200	1,626[3]
Diesel locomotives	300	n a.
Electric locomotives	220	n a.
Freight cars (two axle)	146,000	49,000[3]
Passenger cars	2,600	n a
Trucks	428,000	184,400
Passenger cars	65,600	n a
Busses	6,400	n a
Metallurgical equipment (tons)	102,000	n a
Turbines, steam (kw)	2,906,000	n a
Hydro turbines, large (kw)	372,000	n a
Hydro turbines, medium (kw)	150,000	n a
Hydro turbines, small (kw)	500,000	n a.
Motors, 100 kw and less	624,000	n a
Motors, more than 100 kw	9,000	n a
Machine tools, metal cutting	74,000	53,900
Spinning machines (spindles)	1,400,000	n a
Weaving looms	25,000	n a
Tractors	112,000	80,300[4]
Tractor plows	110,000	n a
Tractor cultivators	82,300	n a
Tractor-drawn seeders	83,300	n a
Threshers, multiplex	18,300	n a
Caustic soda (tons)	390,000	n a
Calcium soda (tons)	800,000	n a
Fertilizers (tons)	5,100,000	n a
Synthetic dyes	43,000	n a.
Felled timber (cu ft)	9,887,920,000	n a.
Sawed lumber (cu ft)	1,377,246,000	n. a
Cement (tons)	10,500,000	n. a
Slate (sheets)	410,000,000	n a
Window panes (sq ft)	861,120,000	n. a
Cotton cloth (linear meters)	4,686,000,000	3,491,000,000[3]
Wool cloth (linear meters)	159,400,000	114,000,000[3]
Leather shoes (pairs)	240,000,000	164,300,000[4]
Rubber shoes (pairs)	88,600,000	n. a.
Hosiery (pairs)	580,000,000	440,000,000[3]
Meat (tons)	1,300,000	3,607,000,000[3]
Butter, dairy (tons)	275,000	n. a.
Vegetable fats (tons)	880,000	495,000[4]
Fish (tons)	2,200,000	1,560,000[3]
Sugar (tons)	2,400,000	n. a.
Flour (tons)	19,000,000	n. a.
Alcohol spirits (gal)	266,283,440	n. a.
Soap (tons)	870,000	n. a.

n. a.—Not available.

[1] Pre-war data combined oil and gas production, the latter having been converted to tonnage figures.

[2] 1946

[3] 1938

[4] 1937.

Union resumed trade in Europe through the medium of bilateral agreements, usually specifying the exact type and quantity of goods to be exchanged. Trade with some 24 countries is covered by these agreements, which are of varying duration The latest arrangement with Czechoslovakia, for instance, concluded in December, 1947, covers a five-year period and trade amounting annually to about 100 million dollars in each direction From the details available on agreements with eastern European countries, it is apparent that the Soviet Union, normally an unimportant factor in the trade of that area, has assumed a role quantitatively more important than that played by Germany before the war.

Because the Soviet government exercises absolute control over its foreign trade, it is impossible to estimate the seriousness of its balance of payments problem The country settles adverse balances in gold and regulates its commerce in keeping with its exporting ability Nevertheless, the U S S R has obtained foreign credits from the United States, Canada, and Sweden since the end of the war The Lend-Lease settlement credit from the U S. amounted to 242 million dollars Canada granted a 3 million dollar credit The Government of Sweden advanced 278 million dollars The Soviet Union is a creditor nation in relation to some of its neighbors as a result of a 29 million dollars gold loan (to Poland), relief shipments of food over and above trade agreement commitments, and through waiving or postponing of reparations deliveries

Number of workers employed, 1947[1]	31,600,000
Average annual income of industrial workers	
1937 (rubles)[1]	3,057
Plan, 1950 (rubles)[2]	6,000
Iron and steel production, 1940	
Pig iron (metric tons)	14,900,000
Steel (metric tons)	18,400,000
Railroads (miles), 1940	62,150
Waterways, 1937 (miles)	63,480
Airlines, 1940 (miles)	87,600
Kwh produced, 1946[3]	47,000,000,000

[1] Including wage earners and salaried employees

[2] "Considerably above the 1940 level," according to the Plan decree

[3] Reconstruction had restored production nearly to the 1940 level of 48 billion Kwh

SWEDEN

Sweden's industry at the end of 1947 was in a strong position, but it was also faced with difficult problems arising from the threat of inflation in the country and from inability to obtain adequate supplies of essential materials. As a neutral during the war, Sweden had been cut off from normal sources of supply and entered the post-war world with a large backlog of demand for imports of all kinds. After years of curtailment, domestic industry was ready for a rapid expansion of activity that has been hampered by continuing shortages.

During the first years after the war, capital investments rose to a higher level than ever before. Many new industrial plants were built, and housing construction reached record figures While many foodstuffs remained strictly rationed, the consumption of such goods as iron and steel, lumber and paper attained new highs Imports increased rapidly, and while the bulk was made up of vitally needed commodities, less essential articles were also imported in large quantities Sweden needs about 10 million tons of coal and coke annually, but during the first post-war years was able to fill only about one-half of its requirements The export siutation, on the other hand, was even more unfavorable. Such Swedish staples as cellulose, lumber, paper, and quality steels were in great demand, but Sweden's export capacity in these fields was smaller than it had been before the war. One reason was the increase in domestic consumption, and another the shortage of fuel, certain important raw materials and manpower In the fall of 1947, it was estimated that the Swedish industry needed about 50,000 more workers.

While Sweden had entered the post-war era in an optimistic mood, the country was confronted with a serious crisis two years later The lack of balance in its foreign trade had grown steadily, and the most critical aspect was an imbalance in trade with the United States, which in 1947 resulted in Swedish import surplus of nearly 300 million dollars Sweden simply was not able to continue to import American goods on such a scale, and in the fall of 1947 severe import restrictions were being enforced Sweden's reserves of dollars, which in 1946 had been very satisfactory, are practically exhausted.

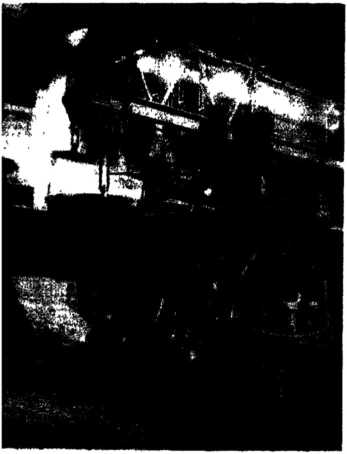
The necessity for drastic curtailment in imports naturally has made the inflation problem seem more complicated than before It is true that price increases during the last year have been smaller in Sweden than in the U S, but the threat of inflation obviously has not yet been staved off Not only will the supply of goods decrease this year, but the supply of money or the purchasing power will increase, a result of increased old age pensions, newly established cash allowances for children of school age, tax reduction for the majority of the people, etc

The government has tried to meet the crisis not only by enforcing severe import restrictions, but also by other regulations, destined to reduce capital investments or domestic consumption, and to increase Sweden's export capacity The construction of factories as well as housing, will be considerably lower this year than in 1947 and 1946 Motor traffic has been severely restricted in order to conserve gasoline, oil, tires, and other accessories. Paper has been drastically rationed, and the quantities thus saved will be exported. The vital importance of increasing production, and especially the production of exportable goods, has been stressed in Sweden recently, but it seems uncertain whether total industrial output can be maintained at the present relatively high level. In August, 1947, the Swedish industrial production index, which is based on 1935 as 100, stood at 129. This

Greasing spherical radial ball bearings at SKF factory in *Gothenberg, Sweden, preparatory for shipment.*

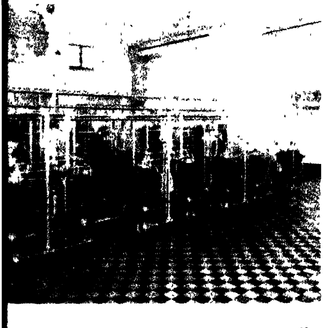
Lathe handles work 10 ft in diameter at the Swedish Bofors *Works. The company's workmanship is known the world over.*

Tapping an open hearth furnace in Sweden's Sandvik Works. Founded in 1860, it owns various mines and power plants.



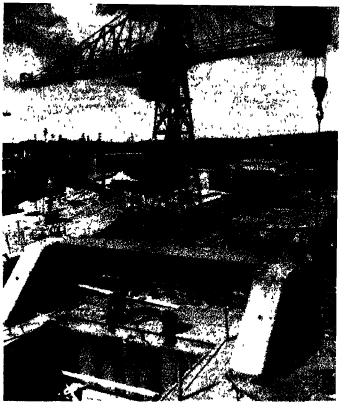
Handling sheet steel in the Svenska Metallverken Works at Vasteras. The company is known for its high grade products.

Operator fitting automatic telephone exchange panels in Telefonaktiebolaget. L. M. Ericsson's factory in Stockholm.

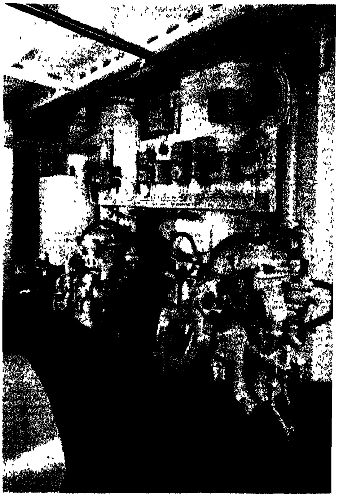


Interior of a typical modern Swedish dairy equipped with a battery of Alfa-Laval separators.

A fully automatic unit for making milk chocolate at the Marabou factory in Stockholm.



Sweden's shipping is important to her economy. Her large shipbuilding yards at Gothenberg are near large steel mills.



Swedish made centrifugal oil purifiers are used on the S.S. Hjelmaren. They are used to clean lubricating oils.

was 2 points lower than the record high reached in July, 1947, and 3 points more than in August, 1939, just before the outbreak of war.

The granting of further credits has been definitely ruled out by Swedish authorities Most of the credits granted have been used, the only important exception being the credit to Russia It was in the fall of 1946 that the Swedish government granted Russia a credit of about 280 million dollars, to be used during a period of 5-6 years When the agreement was signed, it was foreseen that Swedish deliveries would be concentrated at the end of the period, in 1947 they had only started on a very small scale Sweden's industrial difficulties, the full scope of which was revealed in the fall of 1947, made it seem very doubtful whether the country would be able to effectuate the shipments even according to this schedule The Swedish Prime Minister declared that it was obvious that the deliveries, to an even greater extent than was at first anticipated, would have to be concentrated at the end of the 5-6-year period He added, "Should the present difficulties remain or increase, or new difficulties arise which make it impossible to effectuate deliveries to the extent foreseen in the agreement, then Russia's utilization of the credits will automatically be reduced to a corresponding degree" The agreement, in other words, is so constructed that the size of the credits will depend on the ability of Swedish industry to deliver goods

Sweden's industrial difficulties, which are closely connected with the international dollar shortage, should be temporary They do not affect the foundation of its industry For a small country, Swedish natural resources are varied and comparatively well balanced. They have been adequate to make Sweden one of the most highly industrialized countries in the world, with about 40 per cent of the population earning its living from industry and another 20 per cent from commerce and transportation.

From an industrial point of view, Sweden's most important natural resources are its forests, iron mines and water power The country's total supply of timber is estimated at 50,000 million cubic feet, mostly of a high quality The spruce and pine trees grow slowly, forming a firm, long-fibred wood which is ideally suited for the cellulose industry. Vast saw mill and cellulose industries are based on Sweden's forest wealth. Chemical research is opening up new perspectives for the industrial exploitation of wood.

Employed in industry, 1945	758,455
Industrial establishments, 1945	22,071
Average annual income of industrial workmen, 1946	$1,166[1]
Iron and steel production, 1946	
Ingots	1,323,000 (tons)
Rolled	937,000 (tons)
Railroads, 1946 (miles)	10,383
Paved and surfaced highways, 1944 (miles)	65,000
Kwh produced, 1946	14 billion
Telephones, 1946	1,340,000
Trade, 1946	
Imports	$195 million
Exports	260 "

PRINCIPAL MANUFACTURES AND VALUE OF PRODUCTION—1945

(In Millions of $)

Machine shops and foundries	$372
Dairies	245
Iron and steel works	150
Meat packing	140
Confectionery	114
Power stations	107
Pulp mills	103
Saw mills	103

Calculated by the actual iron content, the mining district in the extreme north of Sweden ranks as the third largest iron-ore producing region in the world. Up to 10 million tons have been extracted yearly. There are also some high-grade mines in the central part of the country. The total amount of available water power is estimated at a minimum of 6.5 million kw, corresponding to a potential annual production of 32,500 kwh. For a decade and a half new plants have been built and put into use almost every year, so that production capacity has now been raised to about 14,000 million kwh. About 80 per cent is used for industrial purposes. The importance of electricity to Swedish industry was never more clearly demonstrated than during the Second World War and the past several years, when a shortage of coal constituted one of the country's major worries. In 1947, however, a prolonged drought resulted in a shortage of water power, and electricity had to be strictly rationed This year and in 1949, the annual capacity will be increased by a total of nearly 3,000 million kwh.

In comparison with its size and population, as well as its natural resources, Sweden has a remarkably large industrial activity based primarily on technical ability and intelligent organization. Both coal and most grades of ordinary iron and steel are more expensive in Sweden than in the large industrial countries. Yet Sweden has a vast number of industries making tools, machines and apparatus of various kinds which have been able to hold their own in world competition. Swedish telephones, cream separators, ball bearings, vacuum cleaners, beacons and light-buoys, kerosene stoves, measuring instruments, etc., are internationally known. All of them are the work of Swedish inventors, or owe at least part of their development to them. Other products of the Swedish engineering industry range from watch-springs to ocean liners, and from surgical instruments to large-scale electric generators.

The Swedish shipbuilding industry has an annual production capacity of about 300,000 gross tons, and in 1947 Sweden built more ships than any other country except Great Britain. Most Swedish shipyards are fully booked to at least 1950, which is typical of the situation in the

DATA ON SELECTED INDUSTRIES
1945

	Number of Establishments	*Number Employed*	*Value of Production*[5] *(Millions of $)*
Chemical and allied industries	893	22,857	203
Cement mills and stone products[1]	857	16,443	48
Food processing	4,883	66,865	857
Metallurgical industries	5,517	292,593	859
Electric power generation	876	12,070	107
Pulp and paper industries[2]	1,280	75,835	320
Textiles[3]	1,347	98,966	341
Others[4]	6,418	165,826	492

[1] Includes cement ware industry
[2] Includes printing
[3] Includes confectionery
[4] Includes mining
[5] Converted to dollars at the 1948 rate of exchange $1 = 4.20 kronor

country's whole metalworking industry. Norwegian owners have ordered a total of about 750,000 gross tons from Swedish yards, which largely depend on imports for their supply of iron. While Sweden exports high-grade steels, it imports about 300-400 thousand tons of mass-produced iron a year. Before the war most of it came from Germany, but Sweden now looks to the United States for an important part of this quantity.

In the field of industry, as in many other spheres, Sweden represents an interesting combination of ancient and modern. The country boasts, for example, "the oldest incorporated company in the world," Stora Kopparberg. It was founded in the 13th century for the exploitation of the famous Falun copper mine, and today it is one of Sweden's leading steel and forestry concerns. During the 18th century, Sweden was the world's largest producer and exporter of iron. According to international standards, its production capacity today is small, but Swedish iron and steel is still sold all over the world.

In the Swedish manufacturing industry, the average number of employees per establishment is only 30, compared with 40 in 1913. Production efficiency in small industries, as measured by output per worker, compares favorably with larger organizations. In many parts of Sweden small industry forms the economic backbone of small population centers. It predominates in several lines, such as furniture manufacture, tools, and cutlery. Lately, small industrial firms have grown in importance as subcontractors. The Volvo Company in Gothenburg, for instance, Sweden's largest automobile manufacturer, is essentially an assembly plant, obtaining its parts from about 250 small manufacturers and workshops all over the country.

Approximately 95 per cent of the Swedish manufacturing industry is privately owned, the rest being about equally divided between the government and the cooperative movement. The most important recent government venture in this field is an iron works in the north of Sweden, which was built during the war and whose capacity is now being expanded. It will increase Sweden's output of commercial iron considerably. Most of the country's public utilities are public in every sense of the word.

SWITZERLAND

Switzerland escaped the worst effects of the war despite its being completely surrounded by belligerent nations. With a stable government, industry undamaged, effective rationing and price controls, a sound currency and great wealth, Switzerland is a phenomenal island in a sea of instability and chaos.

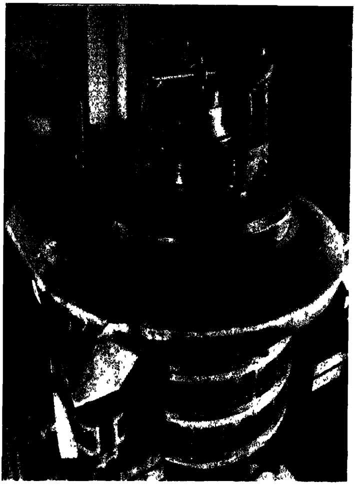
In the first years of peace, the major economic problems have been symptomatic of Swiss industrial progress. With full employment, an acute shortage of skilled labor (estimated recently at 100,000 workers) resulted in the importation of some 50,000 workers in 1946 and even more in 1947. Like most European countries, Switzerland frequently felt the pinch of irregular and insufficient imports of raw materials and coal for industry.

Switzerland lacks food, coal, oil, iron and other materials to sustain itself and must rely upon imports for these goods. It is, therefore, a major trading nation; as much as 90 per cent of many Swiss products is exported. Principal industrial products are watches, precision instruments, machine tools, machinery, chemicals and textiles. The emphasis in manufacturing is on workmanship and superior quality.

Because of its internal economic and political stability, Switzerland has encountered few of the dislocations affecting most other countries in the early post-war years. Strikes are rare, although the cost of living is nearly 60 per cent above pre-war with about 40 per cent of the rise occurring before 1942. Compensating wage increases have pushed the index of wages and salaries even higher. The index stood at 164 at the end of 1946, when the cost of living index was at 154 as based on 1939 = 100.

Shortly after the termination of hostilities, Switzerland opened its borders to tourists and the revival of this important industry has been rapid. More than 200,000 United States Army personnel visited Switzerland after the war. In 1946, the number of ordinary tourists surpassed 100,000 and this figure was paralleled in 1947.

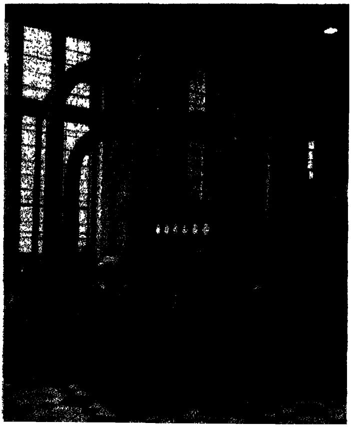
The rapid resumption of trade was made possible by Switzerland's central location in Europe, and by the



Five-stage high-lift hydraulic storage pump built for Etzelwerk A. G. in the Sulzer workshops, Oberwinterthur.

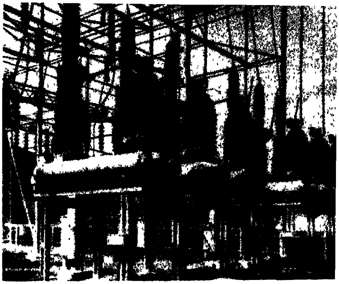
Sulzer axial pump, with a 3.7 to 1.2 m head, 555 hp, during assembly in the Winterthur works, Switzerland.

Two Sulzer oil-free compressors are shown installed in a Swiss brewery.

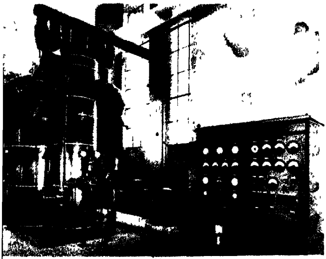


Sulzer boiler feed pump, which delivers 135 tons per hour, installed at Langerbrugge, Belgium.

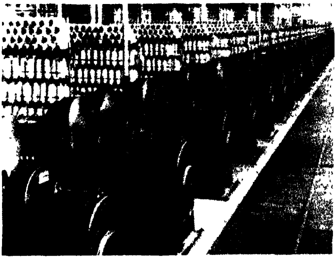
Outdoor three-phase transformers (left) and three-phase auto-transformers (right) at Bern, Switzerland.



Three-pole high speed circuit breakers, with built-on current transformer, built by Brown Boveri



This "Velox" steam generator, recently installed in a Swiss plant by Brown Boveri, operates at 875 deg. C.



Variable speed drives for spinning machines have been installed by Brown Boveri at Spring Mills, Ltd., Bombay.

Two of Brown Boveri's steam turbine driven blast furnace blower sets used by South African Iron and Steel Corp., Ltd., South Africa.

premium placed upon Swiss products by war-devastated neighbors. By a cautious lending policy and strict regulation of trade, the impact of foreign demand has been controlled successfully. Swiss credits have amounted to about 250 million dollars and have stimulated and guided trade expansion More than 20 bilateral trade agreements are in operation governing Swiss trade in Europe.

The principal foreign credits granted since the war include·

France	$70 0	million
United Kingdom	60 0	"
Netherlands	27 0	"
Poland	10 5	"
Belgo-Luxembourg	4 7	"
Czechoslavakia	2 3	"
Norway	1 2	"

The volume of trade since the war has gradually approached, and in 1946 and 1947 surpassed, the level of 1938 The United States ranks first among Switzerland's trading partners

The neutral position held by Switzerland during the war permitted a level of economic activity which was limited only by scarcities of raw materials. The shortage of coal resulted in an expansion of hydro-electric facilities, and throughout the war production of power rose steadily – from 5,375 million kwh in 1938 to an estimated 8,040 million kwh in 1947.

Gold reserves of Switzerland have risen so steadily that the government will no longer accept payment for exports in gold, except under rare and special circumstances In 1938 the gold reserve amounted to 701 million dollars At the end of 1946 the total was 1 430 billion dollars A decline of about 50 million dollars occurred during the first ten months of 1947

SWITZERLAND STATISTICS

Number of people employed in industry, 1945	435,603
Total number of industrial establishments, 1945	9,536
Railroads, 1945, miles	4,864
Highways (miles), 1945	10,200
Telegraph System (miles of line), 1945	1,954,133
Telephones, 1946	645,425
Kwh produced, 1946*	8,352,000,000
Foreign Trade (francs)	
Imports, 1945	1,225,400,000
1946	3,423,000,000
Exports, 1945	1,473,700,000
1946	2,676,000,000

UNION OF SOUTH AFRICA

South Africa, cut off from normal imports, experienced a very substantial industrial expansion during the war years. Production of war materials provided the needed impetus to industrial growth and advanced both the skill of the work force and the technical know-how of management

Most important developments occurred in the machinery, food-processing, chemical, lumber, cement, and leather industries Two new rolling mills were imported from the United States to further the growth of the steel industry Steel capacity more than doubled Dependent upon domestic production for many goods previously imported, South Africa reported that 364 new products were made for the first time at home. New plants were erected to make lactic acid, wax from sugar cane, cellulose adhesives, lacquer, acetone substitutes, glue, gelatin, and chrome salts.

However, South Africa remains dependent upon foreign suppliers for production equipment, and is competing in world markets to obtain the means of expanding its industrial capacity.

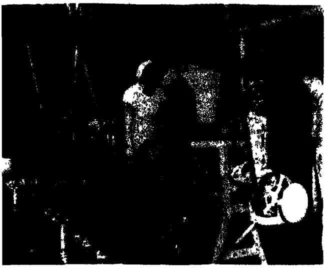
During the war the government created the Industrial Development Corporation of South Africa, Ltd., with a capital of 20 million dollars, "to give assistance and guidance in reorganizing, expanding and modernizing existing industries" By the end of 1945 the Corporation had approved 12 industrial projects and had contributed funds totalling 4.75 million dollars.

Toward the end of the war, the government embarked upon a program of transport improvement, allocating 120 million dollars for railway and harbor works in 1945 alone Railway machine shops, new stations, improvement of track and telecommunications, and electrification of 266 miles of track were undertaken The Post Office Department embarked upon a five-year extension of the country's telephone system, at a cost of 7 million dollars.

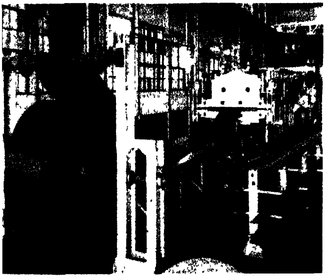
South Africa's steel industry will be enhanced by a new mill being built by Iscor near Pretoria. The new plant will boost annual output to at least 1 8 million tons.

Housing has been neglected in the Union for some years Intensive plans for building include the construction, over the next decade, of 180,000 homes for Europeans and 260,000 for non-Europeans.

United States industry has recognized the importance of South African economy through extensive plans for branch-plant operations The Ford Motor Co is building a 1 6 million dollar assembly plant on a 44-acre site near Port Elizabeth. General Motors has announced the intention of erecting a 4 million dollar plant. Goodyear has a new 1.3 million dollar plant. Firestone is expanding its present facilities. Studebaker intends to build an assembly plant capable of turning out 5,000 units annually. The Pepsi-Cola Co. has announced plans for the construction of six plants in the Union of South Africa, at a total cost of 1.2 million dollars. One of these is already being constructed at Cape Town.



Interior of a typical South African foodpacking house at Paarl, Cape Province, showing operator canning peas.



Conveyor and transmission belting as well as a large tire manufacturing industry are located in South Africa.

Interior of one of South African Industrial Iron and Steel Corporation's plate mills at Vereeniging.

INDUSTRIAL CENSUS OF THE UNION OF SOUTH AFRICA – 1938-39[1]

Industry	*No of Establishments*	*Value of Production (Million £SA)*[2]	*No. of Workers*
Food, drink, etc	2,191	47.7	47,400
Metals, engineering	1,156	30.6	66,151
Building and contracting	990	15.7	38,677
Chemicals, etc	31	12.0	13,364
Clothing, textiles	1,080	11.3	31,005
Heat, light, and power ..	138	10.0	9,309
Vehicles, etc	1,723	10.0	17,373
Books, printing	476	8.0	13,872
Stone, clay, etc	556	7.4	11,065
Leather and leatherware .	303	5.9	14,107
Total (all industries)	9,837	172.8	307,069

[1] In 1940-41, the number of factories was 10,059; workers employed, 390,228, and the value of production, 246 million dollars

[2] The exchange rate in 1939 was £SA = $3.95 (end of year)

Aerial view of recently opened Goodyear Factory at Uitenhage. It will manufacture all types of rubber products.

Heavy earth moving equipment is opening new areas in South Africa by creating and improving transportation facilities.

UNITED STATES

The war years witnessed an unprecedented expansion in the industrial capacity of the United States. American war plants provided munitions for allies in Europe and Asia, and for their own tremendous combat forces mobilized to fight two wars simultaneously at opposite ends of the world. The cost of the war to the United States exceeded 300 billion dollars World reconstruction is dependent upon continued credits running to billions of dollars, and upon the production of American farms, mines, and factories.

The gross national production rose from 97 billion dollars in 1940 to a peak of 199 billion dollars in 1946, government expenditures reached 97 billion dollars in 1944; total compensation of employees more than doubled – from 52 billion dollars in 1940 to 116 billion dollars in 1944.

The end of war prompted many predictions of economic depression arising from the task of adjusting output to peacetime levels In general, it can be reported that the adjustment was made more easily than expected, partly because of the role which the United States has assumed in providing reconstruction aid to many parts of the world.

The first full year of adjustment, 1946, witnessed only a slight drop in total national output: from 199 billion to 194 billion dollars. After a sharp drop in production, the trend moved steadily upward throughout the year Withdrawals of both a permanent and temporary nature shrank the labor force from abnormally high wartime levels so that unemployment was not a major problem

The high rate of personal savings accumulated in wartime enabled the flow of consumer goods to increase as output was expanded, despite the fact that abandonment of controls encouraged a steady rise in prices. With the ending of most controls in 1946, market forces had returned to their traditional role of guiding output and distributing both the factors of production and the products of industry.

At the beginning of 1946, businessmen proceeded upon the assumption that rising sales to the enlarged civilian population and increasing profits were ahead. This was evidenced equally by the aggressiveness with which capital expenditure plans were pushed and the eagerness with which bidding proceeded for available goods. These expectations, with only few exceptions, were realized. In the final months of the year, the culmination of the sellers' market was reached, with the sharpest mark-up of prices for any similar period in history.

Throughout the year, as earlier during the all-out war effort, underlying economic pressures were on the side of demand. These pressures continued to find their source in the current and pent-up requirements of the civilian economy, but the pressures gradually lessened as they were no longer reinforced by the urgent needs of the fighting forces. Thus, the major problem of transition continued to be one of production, but within the special setting and requirements of reconversion. The insistent nature of demand gradually diminished as the increased flow of goods at higher prices quickly cut the rate of savings from current incomes and caused a reappraisal by consumers of both their needs and ability to buy. When this point was reached, the impetus of the price advance was in large part lost.

The year 1946 saw the reorganization of resources and the refilling of pipe lines to permit the resumption of production in industries formerly turning out munitions. The steady uptrend in this area was accompanied by the already high and, in many instances, still rising rates of output in other economic sectors less directly involved in reconversion tasks The result was an annual aggregate of production which, while considerably lower in physical terms than the production of war years, was nevertheless well above the output in the pre-war year 1941.

While it is difficult to make any exact comparison with pre-war, the United States Department of Commerce estimated that the approximate increase in total *real* output was about 20 per cent above 1941. Production was better balanced in relation to consumer needs in 1941 Price increases raised the 1946 value of output to within 3 per cent of the 1945 total and 61 per cent more than in 1941

After the sudden end of war in 1945, and the unexpectedly sharp reduction in military procurement orders, the high level of consumer goods demand served to offset the sharp contraction of production on government account. By early 1946 it was possible for the expansionary forces to assume a dominant role in the economy Further cutbacks in government procurement after that date were more than offset by continued advances in other sectors.

Non-agricultural employment advanced steadily and by the end of 1946 was 5 million larger than at the end of 1945 and 4 million above the 1945 war peak Monthly income payments also moved upward during 1946, exceeding earlier highs. The rise in unemployment during the reconversion period was limited by the strength of the recuperative forces in the national economy and by the large-scale withdrawal from the labor force of war-inducted entrants, mostly women, but including a substantial number of veterans taking advantage of educational benefits under the government's aid program. In early 1946, for instance, a total of 2 5 to 3 million persons were reported without jobs and seeking work. At the same time the number of veterans temporarily delaying their return to work was about 1.5 million

The fact that the economy was in a transitional stage was evidenced in production by the imbalance between output of finished goods and input of labor and raw materials in the durable goods industries. This imbalance was particularly marked while supply lines were being made ready for a steady flow of parts and sub-assemblies. Until such preliminary activities had been completed, there could be only a trickle of finished goods from plants formerly engaged in war production.

The input-output problem was not solved at the end of 1946, and continued to be an influence on the rhythm of production in 1947. Plant operations were interrupted by temporary shortages of materials or the uneven flow of components. Auto plants, for example, offered new motors to the public because motor output ran ahead of body production.

In 1946, the wave of labor-management disputes was a repetition of the national scene after World War I. Trouble began soon after V-J Day when cuts in wage earnings, following reduction in hours and shifts in employment, occasioned a widespread demand for general wage increases At this time the cost of living was comparatively stabilized. Later, when prices were free to rise, a second wave of wage demands occurred. In 1946 the stoppages in production affected wide areas of industry Settlements resulted in a general upward adjustment of wages The outcome of the 1946 difficulties was a rise in average hourly earnings to 11 per cent above the war peak, reached in 1945, and a 4 per cent increase in average weekly earnings.

The sweeping rise in prices after the end of controls outstripped the advance in wages Throughout 1947 the dangers of a rising wage-price spiral became of increasing concern to industry and government, with the return of controls being advocated in some quarters this year.

The rate of business buying during the reconversion period was aggravated by a need for re-establishing inventories at all stages of production and distribution This need was not merely a consequence of bare shelves, empty stock bins and unfilled pipelines, which were a legacy of wartime shortages Large-scale inventory rebuilding was necessary by the reconverted industries whose stocks had become exhausted By the end of 1946 the total book value of business inventories—in the hands of manufacturers, wholesalers and retailers—had risen to 34 9 billion dollars, as compared with 26 4 billion dollars a year earlier Of course, a part of this increase reflected higher prices The market prop afforded by inventory building continued well into 1947.

The rate of business buying in 1946 was augmented by expanded outlays for plant and equipment purchases Pent-up demands were heavy in this field because of restrictions on construction during the war and the difficulty in securing machinery not essential to munitions production Thus, business spending for these purposes climbed from an annual rate of 6 billion dollars in the second quarter of 1945 to 14 billion dollars in the final quarter of 1946.

Clearest evidence of the combined strength of the demand forces in the economy was provided by the rapid rise in prices during 1946, particularly after the end of price controls. The full-year rise amounted to 30 per cent at wholesale and 18 per cent in the consumers' goods price index

After a downturn in industrial activity during the first quarter of 1947, production began an uptrend. Toward the end of the year it was still rising even beyond the expected increases resulting from seasonal factors. Freight traffic was above the seasonal level. Records of sales showed a steady rise after the summer slump. Production advances were widespread, although some production was going into inventories which showed an accelerated rise after mid-summer.

It seemed probable that the figure for gross national product would reach a new high by the year's end; national income was sure to top previous highs, at a figure somewhere around 200 billion dollars. Government expenditures continued to drop throughout 1947 toward a level only slightly above that of 1941 The index of industrial production averaged 190 over the period of the first nine months (1935-39 = 100); coal production seemed likely to return to near its wartime peak As the year drew to an end the Department of Commerce predicted boom conditions ahead in 1948, with the nation entering the new year with production at the rate of 225 billion dollars a year The consensus of economists is that the boom will spend its force before the third quarter of 1948, although a leveling may begin during the second quarter

During the second and third quarters of 1947 the liberal buying policies of business showed in inventory accumulations Department store buying rose in the third quarter and September was the largest order month in the year for manufacturers Prices were rising toward the end of the year, but more slowly Higher farm prices were reflected in rising farm income Urban income was rising with increased employment, and the cashing of terminal leave bonds by ex-service personnel reached its peak in September Residential construction was rising, although seasonally it should have started down before the end of the third quarter The trend of net foreign investment was downward The gross national product in the third quarter was down 3 billion dollars on an annual basis, but showed signs of rising toward the year's end. Foreign needs for relief and rehabilitation continued high, and the European Recovery Program had not yet been accepted as a part of the country's program for European aid

Unemployment dropped to 1,700,000 in October, indicating the advance in business activity This was the lowest unemployment figure in two years The number of persons on unemployment rolls dropped steadily from mid-year on Veteran and state programs registered a drop of 300,000 in mid-October from the previous month.

The rise in the number of persons employed in civilian work to a figure in excess of 59 million in October, 1947, was a contra-seasonal development centered in nonagricultural industries This figure was 2.2 millions above the level at the same date in 1946 Agricultural employment was unchanged from the year before The largest increment to the work force was in manufacturing, amounting to 160,000 between August and September.

Toward the end of the year, wholesale prices were rising and food prices continued strong. Commodities other than food and farm products moved up from week to week. Raw materials prices were strong, with increases in hides, raw cotton, wool tops, rubber, and steel scrap. In the period between May and October, commodity indices surveyed by the Government showed a rise in 34 categories, a slump in 11 categories, with one remaining stable

One of the few counter-expansionary developments late in the year was the trend in U. S. foreign trade. Recorded exports in September were about one-sixth below the average for the second quarter of 1947. The combined effect of a further decline in exports and a rise of more than 10 million dollars in the value of imports in September reduced the excess of exports over general imports to about 630 million dollars, the lowest figure since January, 1947 The excess had been between 800 and 900 million dollars earlier in the year.

The production pattern in 1947 was less uniform than in the earlier post-war period when the reconversion industries were expanding output at a rapid rate and other industries were operating at near capacity During 1947 major heavy goods industries—which still carry a sizeable backlog of unfilled orders—had often been hampered in expanding their operations by relative shortages of supply at various points in the industrial process At the same time, output was reduced in some industries

The explanation for the decline varies for different products In the case of shoes, textiles, wearing apparel, and alcoholic beverages, a reduction in the volume of consumption and the filling up of pipelines may be mentioned With respect to non-ferrous metals, the curtailment in deliveries of semi-finished products to fabricators reflects the heavy concentration of deliveries in late 1946 and early 1947, rather than a fall in consumption by fabricators In building materials, the flow has been at a very high level

There were also periodic declines in 1947 in such manufacturing areas as autos, refrigerators, and railway equipment—where demand was high—as a result of supply difficulties, particularly in raw materials.

The shortages in raw materials is believed to reflect a characteristic of the peacetime consumption pattern In war the high input of labor and more extensive processing caused the index of total industrial production to outstrip the index of raw materials by a wide margin. Now these factors are about parallel since more materials, in relation to labor and processing, are going into production Thus raw materials are a bottleneck, and it appears that the post-war economy of the United States may require a greater quantity of raw materials than in wartime.

Although steel output is just below the war peak, and at a record peacetime level, demand exceeds supply Total deliveries of finished steel products (47 million tons in the first nine months of 1947) indicate an annual total only a fraction below 1944 The full year total for 1946 was 49 million tons

Production in reconverted industries (durable consumer goods) declined in the second and third quarters of 1947 to produce the first reversal of the post-war uptrend Autos, refrigerators, radios (in decline for four quarters), auto tires, washing machines, water heaters, vacuum cleaners, and cooking stoves and ranges began to fall off in the last half of 1947 The tire industry was the first to satiate backlogs of consumer demand

Transportation equipment production was still high – above pre-war levels – with the total number of freight cars being produced at a record level. The backlog of freight car export orders, however, was down from 30,000 to 5,000 in the January to October period. The backlog of orders for the domestic market was 116,000 or equivalent to 15 months' production at the September, 1947, rate. The industry produced 620 passenger railway cars in the first nine months of the year and with 3,000 cars on order as of October 1, had a backlog sufficient to keep going for more than three years at the present rate.

In the first three quarters of 1947 capital invested in new plant and equipment was running ahead of estimates made by business In the second and third quarters investment was at the rate of 4 billion dollars a quarter. The anticipated total for the year was in excess of 15 billion dollars, distributed as follows:

(In Millions of $)

Industry	*1946 Investment*	*1947 (Estimated)*
Manufacturing	5,910	6,960
Mining	560	650
Railroads	570	1,040
Other Transportation	660	880
Electricity and Gas Utilities	1,040	1,790
Commercial and Misc	3,300	3,870
Total	12,040	15,180

During the first nine months of 1947, investment was actually 210 million dollars above business predictions, 410 million dollars above in the second and third quarters, but 200 million dollars below in the first How much of the rise was due to increasing prices and costs is difficult to determine, but must be considered a factor in the equation New machinery and equipment has accounted for 70 per cent of the total new investment, or 10 6 billion dollars

This high rate of capital expenditure is likely to continue well into 1948. Analysis of the capital needs of the country runs contrary to the widely held belief of the 1930's that the United States had reached economic maturity No estimates are available on the amount of capital required to modernize the American industrial system, which is valued at about 200 billion dollars at prewar prices The Twentieth Century Fund has suggested that if as much as one-third of the plant should be replaced or at least rehabilitated, 100 billion dollars (at current prices) would be required.

Other capital will be required to provide adequate and improved housing and to maintain public works By 1960, it has been estimated, housing may require 115 billion dollars. To modernize city streets and rural highways would cost 40 billion dollars over a 15-year period. With these estimates at hand, economists see little chance that needs will not be found for all the capital which may become available

Capital requirements for industry are greater today than at any previous time, and the backlog at the end of the war was set at 30 billion dollars At least 27 billion dollars had been liquidated during 1946 and 1947, but new needs have arisen and new plans have been formulated.

There is also a huge foreign demand for U. S. capital. The European Recovery Program sets the needs at more than 16 billion dollars, to be met by government. If foreign investment follows the proportion of the late 1920's, the rate would be about 1.5 billion dollars a year. United States foreign investments abroad were estimated at about 14 billion dollars in 1947.

A rising volume of foreign trade which will permit foreign nations to earn sufficient dollars to pay interest on American development funds constitutes a prerequisite to a healthy rate of foreign investment The United States government has granted more than 10 billion dollars in repayable loans since the end of the war to provide the basis for recovery and modernization of foreign economies, with a view to obtaining repayment in the years following 1950 or 1951 Some of the loans will be repaid over 30 or more years Repayment will be a constant sizeable drain on foreign dollar earnings to which will be added the transfer requirements of current and future private investments By 1947 the volume of world trade had grown rapidly toward the pre-war level, and should attain that level in most areas this year, surpassing it in some Continued high levels of industrial activity in the United States will raise its requirements for foreign raw materials and manufactures and be the most effective stimulant to an expanding world trade

A further incentive to capital investment in the United States now and in the future will be the new methods, materials and products developed during the war or postponed as a result of wartime concentration on munitions production Some of the most important war developments with peacetime applications include new chemical processes and products, including synthetic rubber, plastics, synthetic fibers and fabrics, new food products and new methods of food processing, new uses for glass, plywood, and light metals, advances in aviation, and new industrial applications for atomic energy New industries will evolve from the further use and exploitation of these developments

Business expenditures for plant and equipment continue high, and this trend promises to continue through 1948 According to figures issued jointly by SEC and the Commerce Dept., it is anticipated that American business will spend 4 1 billion dollars in plant and equipment the first quarter of this year. This is almost a billion more than during the corresponding quarter of 1947, and only 340 million dollars less than for the fourth quarter of 1947.

DISTRIBUTION OF NON-AGRICULTURAL EMPLOYMENT

	1946	*1947*
Manufacturing	15,035	15,696
Mining	884	893
Construction	1,747	1,924
Transportation and Public Utilities	4,064	4,141
Trade	8,523	8,700
Financial, Services, etc	5,990	6,218
Government	5,605	5,425
Total	41,848	42,997

U S Dept of Labor, Bur of Labor Statistics

UNITED STATES STATISTICS

Number of people employed in industry, 1947	15,816,000
Manufacturing only, Mining 895,000, Construction 1,883,000, Total non-agricultural employment 43,257,000	
Total number of industrial establishments, 1939	184,230
Total capital invested in all industry, 1947, (estimated)	$200,000,000,000
76,765 employed five or fewer workers	
Average annual income of industrial workers, Oct 1947 rate	$2,650
Iron and Steel production, 1946	
Steel ingot and castings	66,364,000 tons
Railroads, 1944 (miles)	227,335
Surfaced Highways, 1941 (miles)	1,607,000
Includes city streets and alleys, accounting for 223,000 mi of the total	
Kwh produced, 1946	269,544,000,000
Telephones, 1946	27,867,000
Foreign Trade, 1946	
Exports, including re-exports	$9,738,000,000
Value of Lend-lease, included in Exports	654,000,000
Imports, general	4,934,000,000

The raw materials required by an expanding United States economy will encourage expanded domestic output and increase the volume of imported primary products It has been estimated that the demand for raw ma-

EXPENDITURES FOR PLANT AND EQUIPMENT

(Figures in Millions. 4th quarter of 1947 and 1st quarter of 1948 are anticipated expenditures)

Year	*Total*	*Mfg*	*Commercial Misc*	*Mining*	*Gas & Elec.*	*Railroad*	*Other Transp*
'46-1	2200	1100	580	110	180	100	130
'46-2	2800	1400	740	130	230	130	170
'46-3	3310	1650	890	160	280	160	170
'46-4	3730	1760	1070	160	360	180	200
'47-1	3160	1450	900	150	330	160	180
'47-2	3940	1850	1030	160	450	220	230
'47-3	4140	1870	1160	180	500	230	200
'47-4	4440	2040	1100	190	550	370	200
'48-1	4100	1810	1080	170	490	360	190

Credits: U. S. Dept. of Commerce and Securities and Exchange Commission.

terials will be one-third above the 1940 level by 1950, and 50 per cent greater by 1960. Using 1940 as the base year (100), the Twentieth Century Fund* compiled the following estimates of U S requirements for these two dates, and compares them with the wartime peak:

	Wartime Peak	*1950*	*1960*
All Minerals	138	133	151
Metals	157	117	126
Fuels	130	141	164
Other	141	128	142
Lumber	126	93	76
Electric Power	159	173	224
Manufactured Gas	120	94	75

In summary, it can be asserted that the post-war boom in industrial activity in the United States had not been spent as the year 1947 ended, and there were few indications that a general decline could be expected before the middle of 1948. The degree of the anticipated recession will depend upon many complex factors affecting business activity and consumer buying, but since most pessimistic predictions for an earlier and deeper depression have been inaccurate it is likely that the 1948 dip will be shallow and of short duration. The continuing high level of investment and the insatiable demands of the foreign market are signs that point to strength in the economy this year.

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* "America's Needs and Resources," Twentieth Century Fund, 1947, New York

ECONOMIC INDICES

	1939	*1946*	*1947 (Estimated)*
Gross National Production (billions of dollars)	88.6	194.0	230.0
Government Expenditures for goods and services (billions of dollars)	16.0	34.7	28.2
National Income (billions of dollars)	70.8	165.0	200
Farm Marketings (volume, 1935-39 = 100)	109	138	140
Industrial Production (1935-39 = 100)	109	170	192
Bituminous Coal (millions of tons)	395	532	600
Electric Power (billions of kwh)	161	269	297
Steel Ingots and castings (millions tons)	53	66	84

ACKNOWLEDGMENTS

In compiling this body of data and industrial information, particular appreciation must be expressed to those cooperative government and semi-government agencies which have given so unstintingly of their time and labor Several public relations firms have also assisted in the preparation of this 1948 issue of the INTERNATIONAL INDUSTRY YEARBOOK by arranging for the collection and presentation of data by the governments which they represent The text for a large part is the product and research of individuals who have furnished the requested information to us on their countries' industrial economy

Particular thanks are expressed to Mr. Harold P. Breen, Director of Australia's Commonwealth Secondary Industries Division, Department of Post-War Reconstruction; Mr. H W. Eather, New York Office of the Government of the Commonwealth of Australia, Dr. V. Fleischer of the Czechoslovak Embassy, Mr Viggo Jensen, Consul, and Mr. Torkild Albertson, Secretary, of the Danish Consulate General; Commissariat General du Plan (France) and Miss Yvonne Daumarie, Assistant Director of the French Embassy; Mr J A. Stiles, Canadian Trade Commission of the Canadian Consulate in New York; Mr X. F. Drexler of the Swiss Consulate General; Dr. W. Van Cauwenberg, Consul, Belgian Consulate General; Mr. Herman Holm, Secretary of Industriens Utredningsinstitut (The Swedish Institute for Industrial Research), Stockholm; Mr. C. Raphael and Mr. H. D. Davis of the Economic Section, British Information Services; the personnel of the British Board of Trade, London; British Information Services, Mr. Ivan A. Jacobsen of the Royal Norwegian Information Services; Mr L Smilde of The Netherlands Chamber of Commerce in New York, and The Hamilton Wright Orzanization, Inc.

All statistical data and other materials have been obtained from official sources and insofar as possible directly from the governments themselves.

Illustrations for this chapter were obtained through the courtesy of McGraw-Hill World News, Administracion General de Vialidad Nacional (Argentina), Standard Oil Co (N. J), South Australian Government Photos, Australian Commonwealth Department of Commerce and Agriculture, Allis-Chalmers Manufacturing Co., Brazilian Business, *Brazilian National Steel Co., Oscar Kohorn & Co., Ltd., American & Foreign Power Co., Cia Paulista de Forca e Luz, Nicaro Nickel Co., National Film Board (Canada), Polymer Corp., Monetary Times, Czechoslovak Embassy, French Press & Information Service, Tata Iron & Steel Co., American Iron and Steel Institute, Caterpillar Tractor Co., Westinghouse Electric Manufacturing Co., Royal Norwegian Information Services, Commonwealth Secondary Industries Division (Australia), Brown Boveri Corp., Sulzer Bros., Ltd., Sovfotos (Russia), American Swedish News Exchange, Inc., Government Information Office of the Union of South Africa, South African Railways and Harbours, Wide World Photos.*

CHAPTER II

INDUSTRIAL RESEARCH

by Jesse E. Hobson

The application of basic scientific knowledge, through applied research, to the problems of government and industry was given great impetus during the war when the research laboratories were so successful in meeting a situation of national emergency The post-war needs for technological developments are only a degree less urgent, and we find both industry and government engaged in a large-scale program of scientific activity Research, both basic and applied, has become a major resource in all phases of our economic development Viewed in any light—expenditures, manpower, contribution to the nation's industrialization, a guarantee of national security, or promotion of general welfare—research has become big business, and research has become a major profession (1, 2).

RESEARCH IN INDUSTRY

A situation of increased labor costs and higher taxes, as well as a more difficult competitive situation between industries and between companies within an industry, is causing more emphasis to be placed on the application of scientific knowledge for the development of new products and processes, for the reduction of production and service costs, and for the improvement in quality of existing products. The past year has seen a marked expansion of investment by industry in industrial research in existing laboratories (3), in the development of new laboratories and in research "farmed out" to independent laboratories and to universities (4).

The National Research Council reports 133,515 persons now employed in more than 2450 laboratories of industry, an increase of almost 100 per cent over the total personnel of 70,000 reported in 1940 (5). The rapid increase in number of laboratories and in laboratory personnel since 1915 is of interest and indicates a long term trend In 1915 there were only 100 such laboratories Five years later there were 300, employing 9300 persons By 1930, 34,000 persons were employed in 1625 laboratories.

Artist's sketch of new Merck research building now nearing completion in Rahway, New Jersey.

Included in the present total of 133,515 there are 55,000 professional personnel as compared with 35,000 total in 1940 A smaller percentage increase of professional personnel than total personnel is an indication of the growing shortage of scientists and engineers, particularly those with advanced training

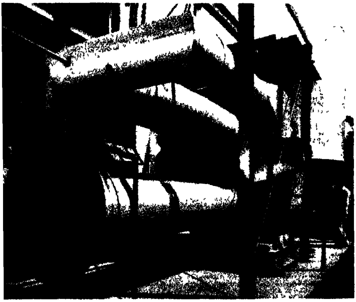
According to the National Research Council, the distribution of professional personnel in the laboratories of industry among the branches of science, is:

Chemists	*21,095*
Biologists	*1,695*
Engineers	*20,637*
Doctors of Medicine	*236*
Physicists	*2,660*
Metallurgists	*2,364*
Psychologists	*22*
Geologists	*81*
Not classified	*5,367*

Although John R. Steelman in his report to the President, *Science and Public Policy,* estimates the annual industrial expenditures for research at $450,000,000, others are inclined to place the probable expenditures nearer $600,000,000 or $700,000,000 (6). In any event, the expenditures have increased approximately 100 per cent since 1940 A recent survey by the Patents and Research Committee of the National Association of Manufacturers disclosed that expenditures by the Association's members for 1947 will have been 270 per cent above 1939 and 14 per cent above 1946. Several companies reported that their 1947 research and development budgets were more than 10 times their expenditures in 1939 Research programs are carried on by 750 of the 983 companies covered by the NAM survey. The replies further indicated an average ratio of research investment to gross sales for 1947 of 1.6 per cent compared with 1.86 per cent for 1939.

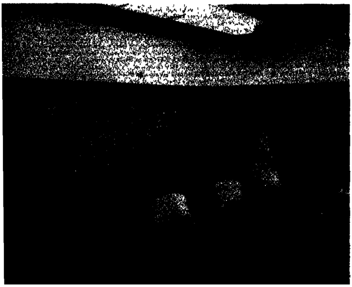
Business Record, a publication of the Industrial Conference Board, New York, for March, 1947, reports in *A Survey of Business Practices* that the median percentage of the sales dollar spent on research falls between 1.5 and 2 per cent, with some companies spending as much as 5 per cent, and a very small minority

Pilot plant for research on manufacture of industrial insulations at the new Johns-Manville research center.



One of Battelle's recent accomplishments in metals was the successful welding of thick slabs of aluminum.

Available to industry is the network calculator laboratory at Armour Research Foundation.



allocating little or nothing to research and development. This survey also shows that most companies report a higher percentage of the sales dollar spent on research and development than before the war. It further points out that where the ratio may be below the pre-war rate, or at the same level, aggregate research expenditures in many instances show a sharp rise over 1939 or 1940 This point is illustrated by the record of a railroad equipment company which showed 1.1 per cent of sales spent on research both in 1946 and 1939, but with total expenditures in 1946 amounting to $852,000 as compared with $273,000 in 1939, a gain of 212 per cent.

A survey, *Research Requirements of American Industry*, made recently by the Evans Research and Development Corporation, concludes that 87 1 per cent of industry as a whole is spending more for research than pre-war, 10 6 per cent the same as pre-war, and only 2 3 per cent spends less than pre-war Further, 86 1 per cent of all industries benefited from their wartime research activities It is significant that 72 5 per cent expect to increase their research activities in the future and that 60 per cent expect to expand their facilities. At least two years are needed before industrial research can be brought to the desired level, according to 45 per cent of the reporting industries

The same survey reveals that 47 6 per cent of industry invests funds in research to improve present products and processes, 42 3 per cent to develop new products and processes in their own fields, and 14 7 per cent to develop products and processes in other fields

Barron's National Business and Financial Weekly, in an article by Robert M Bleiberg appearing February 17, 1947, states as examples of current expenditures for research:

"The American Cyanamid Company, for example, spent almost $7 million in 1945, six years before it spent less than $2 million The Bendix Aviation Corporation presents an even more striking picture Its research and engineering expenses for 1945 were approximately $18 million as contrasted with a 1939 figure of $2 5 million International Business Machines Corporation more than doubled its pre-war budget of $1 million. Addressograph-Multigraph, Monsanto Chemical, Westvaco Products, American Smelting and Refining, Allis-Chalmers and a host of others had like stories to tell. The figures vary, but the principle remains the same—these corporations all regard money spent for research as a definite investment and are pouring more funds into it, as they would into any investment that has proved its profitability."

No one can accurately predict the future budgets for research by industry (7, 8, 9). One thing, however, is certain—industrial budgets for research not only will increase but *must* increase if American industry is to keep its place as the leading industrial nation of the world and if it is to maintain its position in world trade (10). Several leaders in the research field have predicted that research expenditures will be doubled within the next ten years, so that research by industry alone will exceed one billion dollars.

Certain factors will inevitably increase the costs of industrial research and perhaps decelerate an extension [illegible] of the rapid growth witnessed during the past several years. The shortage of trained scientists and engineers created by war-time reduction of college training will certainly increase research salaries. Many scientific problems can now be solved only with the use of intricate and expensive scientific equipment and through the cooperative efforts of research teams specialized in several fields. Furthermore, the costs of productive research developments increase as the scientific frontiers are rolled back. In spite of increasing costs, industry is well aware of the benefits of research, and, to an increasing extent, considers its research expenditures as a vital and necessary investment for future security (13, 14).

Only a few examples of returns on research investment, as reported by industry, will serve to illustrate the recognition being given to results of scientific research.

A major oil company reports a return of $15,400 to its stockholders for every $1000 invested in research over a 10-year period.

A pharmaceutical company, reviewing its records of research investment for the past 20 years, finds a return of 100 per cent on research investments.

One third to one-half of the products of one of the largest electrical manufacturers had their beginning in the research laboratory.

A large chemical company states that 80 per cent of its sales consist of products developed through research since 1936.

An industrial machinery corporation reports a tenfold sales increase since 1937, and credits 80 per cent of the increase to new products.

Surveys have indicated that 50 per cent of the total employment in the United States is based on products coming from the research laboratories—thus one research man has created employment for almost 200 persons.

A. W. Robertson, Chairman of the Board of Westinghouse Electric Corporation, has emphasized that manufacturing research has reduced the cost of countless products. He cites as an example the 100-watt incandescent lamp which once sold for $2.00 and now costs just 15 cents; and the present product is a far better lamp, giving twice as much light for the current it consumes. In a project to improve electric motors, research engineers developed a motor 35 per cent smaller than its predecessor, but which produced 134 per cent more power for each pound of weight.

Mr. C. G. Worthington, Executive Secretary of the Industrial Research Institute, an organization comprised of many leading industrial concerns of the United States, writes:

> "Over the past twenty years American industry has come to recognize the need for research as indispensable to its progress and security. A large number of industrial research laboratories has been established and the number and size are increasing rapidly.
>
> "The volume of work done, the number of skilled personnel engaged, and the amount of money expended have given rise to many managerial problems which are common to all research organizations. These include such questions as organization and functional operation of the research department; personnel selection, training, compensation, and maintenance of morale; selection and control of projects; budgeting and accounting, evaluation of research results; patent policies and practices, the fitting of research into the corporate structure, and relations with government, universities, and outside organizations. Industrial Research Institute was founded in 1938 to provide industrial research executives with an organization for the cooperative study of these problems and thereby to promote improved management of industrial research.
>
> The Institute was originally organized under the auspices of National Research Council with fourteen companies forming the nucleus of membership. It was incorporated in 1945 as an independent non profit membership organization. The membership has increased roughly sevenfold in ten years.
>
> "The Institute has found that one of the best means of accomplishing its objectives is through periodic meetings at which information and counsel on research management problems are exchanged by member executives. The general practice is to keep the proceedings confidential in order to promote free and frank discussion. However, papers and reports which are felt to be of general interest and value are published in outside journals.
>
> "Extended studies on subjects of special interest are made and reported to the Institute by member company representatives, committees, or staff members. An exchange library of forms and manuals used by members in their administrative routine is maintained by the headquarters office.
>
> A medal established by the Institute as a high honor for outstanding contributions to the field of industrial research is unique in that it is given primarily for management leadership in industrial research. It has been awarded to Willis R. Whitney of General Electric Company and to Charles A. Thomas of Monsanto Chemical Company.
>
> Prompted by the meagerness of published information on the organization and management of research in industry, the Institute undertook the preparation of a comprehensive monograph, *Research in Industry, Its Organization and Management*, which will be published by D. Van Nostrand Company of New York early in 1948. It is hoped that it will serve both as a useful reference for research directors and their administrative staffs and as a textbook for graduate courses in research laboratory management.
>
> "There is a growing trend in industry to promote to top management positions those in an organization who are chiefly responsible for its technological progress. Interest in research management is not reflected alone in the growth of the Institute as a national organization. Local groups of research directors have organized informally in several important research centers of the country (notably Boston, New York, and Philadelphia) for continuing discussion of their special problems. Regional conferences on the management of research also are beginning to be held about the country."

Effect of selenium in soil to control aphids on flowers is studied at Battelle Memorial Institute.

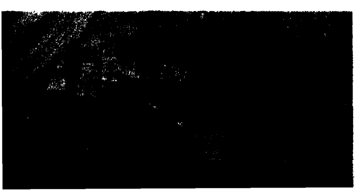
Numerous corporations are building new research laboratories to extend present facilities or to replace obsolete facilities It has been estimated that more than 200 new laboratories were constructed between 1940 and 1946. In the reference cited above to *Barron's Weekly*, Bleiberg points out that almost a dozen multimillion dollar projects have been built or are in the planning stage. These include a $2 million laboratory built by Firestone Tire and Rubber Company and put into operation in 1945 The Radio Corporation of America will double its existing laboratories at Princeton, New Jersey. General Electric Company has announced a $10 million project for electronics laboratories. The General Motors Corporation is planning a research and technical center, estimated to cost more than $20 million and intended to bring together the product research and experimental facilities of the company.

The F W Dodge Corporation reports that contracts were awarded for 289 projects classified as "laboratories, — science buildings — educational and commercial laboratories, observatories and planataria," during the first eleven months of 1947 in the 37 states East of the Rocky Mountains Contracts for these laboratories call for the expenditure of $61,882,000. These figures compare with contract awards for 301 projects costing $58,351,000 during the corresponding period of 1946.

The H K Ferguson Company has designed and built three major research laboratories during the year· Allied Chemical and Dye Corporation at Morristown, New Jersey, to centralize that firm's research activities; Bristol Laboratories at Syracuse, New York, for the production of penicillin and the study of new anti-biotics, and, Parke-Davis and Company at Detroit, Michigan, for the production of streptomycin and the study of new anti-biotics. Scientists and researchers in the field of anti-biotics are confident that they have only touched the surface, and that penicillin and streptomycin are merely spearheads in the fight against disease. Bristol points out, in announcing the new laboratory, a policy common to many progressive organizations—a long-range factor that had to be considered was that facilities and plans must be ready to capitalize on future discoveries made in the research department. Not to have such facilities ready at the proper time would undoubtedly be more costly than present building costs in terms of a competitive position in their industry.

The Johns-Manville Corporation, on October 16, 1947, unveiled its research center and pilot plant, and laid the cornerstone of the second unit, of a new research center group This group will ultimately include five or six units, providing 337,000 sq ft of laboratory space, and is located on a 93-acre tract 40 miles from New York City. Modular design is used to give an assembly of standard work space units for maximum flexibility This laboratory center is said to be the largest in the world devoted to building materials, insulations, and allied industrial products.

Experimental greenhouse at the Midwest Research Institute for testing agricultural fungicides.



Merck and Company has considered research a most essential part of its activities. In 1933 the company completed its first building devoted exclusively to this function Laboratories now occupy almost 100,000 sq ft of space in 5 modern buildings Work on a large new addition to the laboratories was started in 1946, and it will probably be occupied in 1948 Emphasizing a trend in new laboratory construction, the new building will be extremely flexible, with the basic unit of its facilities comprising a small, complete laboratory unit with all necessary facilities. All partitions, except exterior and corridor walls, will be easily movable panels permitting the grouping of a number of units to form a laboratory of almost any size and shape It is of further interest that the laboratory staff now numbers 510 persons, with a technical staff of 250, and that the research expenditures were $3,438,279 in 1945 and $3,216,845 in 1946, close to 6 per cent of the sales dollar

Greatly increased research activity by trade associations and organizations also demonstrates the growth of industrial research by all companies both large and small. More than 125 associations were conducting research for their member companies before the war, and that number has steadily increased. A pending publication of the Department of Commerce, *Scientific and Technical Research Activities of Trade Associations*, edited by Gustav E Larson, summarizes work done by trade associations in their laboratories and in the laboratories of consulting, independent, non-profit, and university organizations (17). Associations, such as the American Institute of Laundering and the Structural Clay Products Institute, are considering substantial increases in their research programs. Well established research activities such as those maintained by the Lithographic Technical Foundation recently have been revitalized and expanded. Larson's report states that at least 35 trade associations now maintain or operate their own laboratories, and these laboratories employ 800 to 1000 personnel, exclusive of fruit grower and processing groups. Among the larger laboratories are:

National Board of Fire Underwriters	171 Persons
American Gas Association	120 persons
National Canners Association	44 persons
Portland Cement Association	37 persons
American Meat Institute	31 persons
American Institute of Laundering ...	30 persons
Tanners' Council Laboratories	25 persons

Many associations use government laboratories, such as the Bureau of Standards and the Forest Products Laboratory, university laboratories, or non-profit research institute laboratories.

Much of the research done by trade associations is [illegible] for small companies, although association activity is by no means confined to the smaller industrial organizations. Small companies are becoming increasingly conscious of their dependence on research to maintain a competitive position within an industry and to meet the technical developments made by competitive industries which can, and frequently do, threaten an entire industry with obsolescence and decay The National Research Council in 1940 surveyed 50 small companies having assets ranging from $150,000 to $2,500,000 Twelve companies stated "if we should immediately cease all forms of organized fact-finding in which we are now engaged, we would be forced out of business within a year" Six stated they would be liquidated in three years and seventeen would at once experience a serious loss of competitive position

The American Gas Association recently stated that $250,000 a year must be spent on research if the gas industry is to keep its services in line with that of competitors.

The National Lumber Manufacturers' Association has prepared a master list of 250 technical problems which must be solved through association research if the lumber industry is to hold most of its present markets

The National Canners' Association will continue to spend $200,000 to $300,000 annually in work in its own laboratories and in other research agencies

Contrary to the pattern established in England where trade association research is substantially subsidized by the government and where association research forms a major part of research activity by industry, the Government of the United States has assisted association research only to a very limited extent There has been recently, however, a decided tendency on the part of government to assume a much greater role in financing and organizing association research (18) This tendency, supported in some quarters, has been vigorously opposed by some sectors of industry for reasons of patent policies, paternalism, alleged inefficiency of government supervision, etc.

Scientific and industrial research by both large and small companies is definitely on the ascent. It is being recognized generally as a necessary part of business operation, and is assuming an ever expanding position as a part of the corporate structure (20, 21).

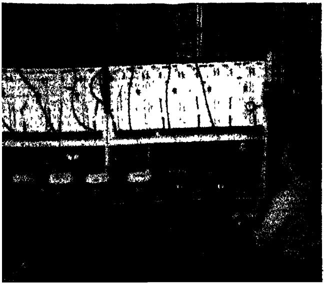
RESEARCH IN COLLEGES AND UNIVERSITIES

Today, as has always been the case, the basic source of progress in fundamental sciences resides in the laboratories of colleges and universities. Pushing back the barriers that cloak and obscure the trails of scientific advancement are, and should be, the main considerations of research in the university graduate schools To a considerable extent many sources of basic scientific knowledge were located in Europe prior to the last war, although several colleges and universities in the United States had made notable contributions The disruption of foreign sources of fundamental scientific work, the drain on the stock-piles of scientific knowledge accelerated by wartime applied research, and the increased pressure for pushing back the frontiers of knowledge to provide basic information for post-war developments, have greatly increased the demand for fundamental scientific activity in university laboratories.

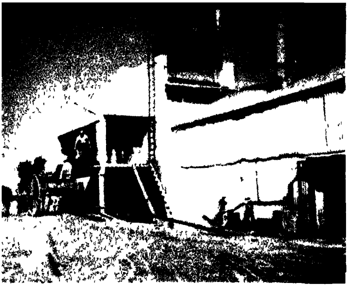
The increased demand for scientific research by the universities has come at a time when increased student enrollments have taxed the teaching staffs to such an extent that much less time is available for research investigations Funds from endowments are less plentiful because of lowering interest rates. It is exceedingly difficult to attract and maintain an adequate staff because of the shortage of qualified scientists and the competition with higher salaries in industry

Universities have been quick to recognize the need for further basic scientific research and to meet the challenge offered to an accelerated research program by difficult post-war conditions. Most educators, and research men feel, however, that financial assistance from industry and government is urgently needed if their obligations are to be met. They emphasize that finan-

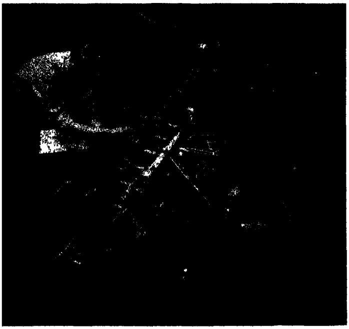
Stream pollution control being studied in a comprehensive project currently underway at Mellon Institute.



High speed camera studies of research on textile operations at Southern Research Institute.

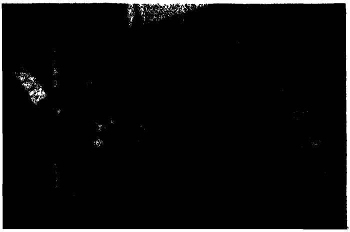


Inspection of Argentine cheese factory by Armour Research Foundation is part of technological audit.



Development of new aircraft engine bearings requires a thorough study of different alloys and designs.

Cold starting tests are one example of experimental work that results in improved operation and design.



cial assistance must be given without restraints as to publication, patent protection or supervision if research in fundamental science is to be effective.

Industry is recognizing to a greater extent its obligation to finance scientific training and basic research, as evidenced by the increased number of industrially sponsored fellowships and grants. Research fellowships and scholarships supported by industry now total 1800, compared with a total of 90 during 1929 The number of firms supporting such grants has grown from 56 to more than 302 and a number of other companies report their intention to provide such support and assistance as soon as facilities and personnel are available

The Federal Government also recognizes its responsibility to give additional assistance to the universities Although the legislation for a National Science Foundation, as passed by a large majority of the 80th Congress of the United States, was vetoed by the President, Congress seems to be united in feeling that financial assistance must be given for scientific training and research It appears probable that assistance in some form will receive the early attention of Congress.

Several government agencies have placed research contracts with colleges and universities The majority of such contracts have not contributed greatly to the furtherance of basic research, but rather have been directed toward the application of existing scientific knowledge An outstanding exception has been the Office of Naval Research which has maintained a broad program of basic research in the physical sciences and in medicine Approximately 80 per cent of this program is conducted by the colleges and universities, and about 50 million dollars was obligated by the end of 1947

The universities went from a wartime total of about 20 million dollars annually to a present rate of annual research expenditure of about 80 million dollars. Some 300 or more universities are now engaged in either basic or applied research. More than 75 members of the Engineering College Research Council offer to accept projects from industrial sponsors.

The 1947 Directory of the Engineering College Research Council lists the facilities, major fields of investigation and volume of sponsored research of the leading engineering educational institutions (22).

Several colleges, universities, and technological institutes have established research foundations or institutes. Some of these organizations are integral parts of the educational institution, some are closely affiliated with it but exist as separate corporations and others are independent non-profit corporations with a more-or-less close affiliation (23). Contractual relations, patent policies, publication policies, and charges for industrially sponsored projects vary widely between organizations (24). It is evident that economic pressure has been a dominant factor in causing many universities to seek applied research projects supported by industry.

Many individual scientists, research leaders and educators have pointed out that investigations in the field of applied research do not often contribute substantially to the primary university function of scientific education, graduate study and basic research. "When industry supports basic research, the effect upon the university is a salutory one," states David Gordon of David Gordon and Co. Dr. Jacques Errera, speaking at a recent meeting of Consulting Chemists and Engineers, cautioned that the role of the university is two-fold: First, it must educate; it must supply the bachelors, masters and doctors who will carry on the nation's research and development program. This activity must be self-supporting on a high level. For this support we must look to both private and public funds. Second, the research function must involve basic research.

Certainly there is a trend toward increased scientific activity in the universities and colleges: increased college enrolments at all levels in scientific education, additional emphasis on graduate research and basic scientific research, and increased desire on the part of the colleges to seek industrially sponsored research, a part of which will contribute to the primary functions of scientific education and research.

PUBLIC SERVICE RESEARCH ORGANIZATIONS

Several types of organizations have been established to render a service of scientific and engineering research to industry and government on a fee basis. These organizations include the consulting laboratories of such firms as Arthur D. Little, Carl Miner, Foster D. Snell, and others; engineering research and development laboratories such as Barnes and Reinecke, Buehler and Company, Mast Engineering Company, Engineering Research Associates, etc; and the non-profit research foundations and institutes such as Franklin Institute, Mellon Institute of Industrial Research, Battelle Memorial Institute, Armour Research Foundation of Illinois Institute of Technology, Midwest Research Institute, Southern Research Institute and others. Some of the latter institutes have a more-or-less close affiliation with an educational institution.

It is of particular interest to survey the activities of the leading non-profit research institutes, since they reflect the diversity of scientific activity undertaken by government and industry, since they work simultaneously in several industrial and scientific fields, and since their growth and activity roughly parallels that of all industrial research in the United States. Further, these institutions form a pattern unique among research organizations which is being studied and copied throughout the world. The primary objective of such institutions is to render a confidential research and engineering service to industry and government on a cost basis. They have, moreover, important secondary functions of promoting and furthering fundamental research and of supplying men, trained in the approach and techniques of applied research, to the laboratories of industry and government.

The non-profit research institutes do not intend to compete with existing commercial laboratories, testing laboratories, or consulting engineering firms since they are established on a basis of tax exemption. They make every effort to accept projects which do not compete with research services available elsewhere. Projects are accepted on a confidential basis, with full patent and publication protection given to the sponsor.

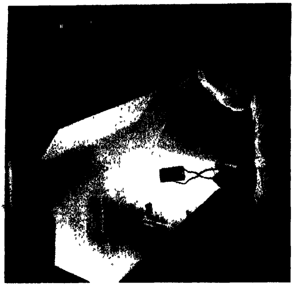
The Battelle Memorial Institute, in Columbus, Ohio, is such a non-profit, privately endowed institution founded in 1929 by a bequest from Gordon Battelle (27). Income from the bequest has been used to provide buildings and equipment and to support an active program of fundamental research. The volume of industrial and scientific research conducted at Battelle Institute in the calendar year 1947 will amount to approximately $4,250,000, an increase of 24 per cent over the volume for 1946 which amounted to $3,425,000. The research activities cover diverse fields. A rough division of this activity in broad fields during the first six months of 1947 was.

Metallurgy	25 per cent
Chemistry	20 " "
Physics	17 " "
Fuels Technology	12 " "
Ceramics	6 " "
Mineral Processing	4 " "
Welding	4 " "
Production Research	4 " "
Graphic Arts	4 " "
Miscellaneous	4 " "

More than 250 investigations were in progress during the year, 60 per cent of which were for industrial sponsors and 40 per cent under sponsorship of government agencies. The staff of the Institute numbered 860 on January 1, 1947. By December 1, 1947, the staff had grown to 1,028, of which 60 per cent are trained scientists, engineers and technicians, and 40 per cent are administrative and service personnel.

The Mellon Institute of Industrial Research is the outgrowth of a plan originally conceived in 1906 by Dr. Robert Kennedy Duncan. The fellowship system was designed to provide scientific research facilities and personnel for public use. Evolved to give manufacturers the privilege of establishing a temporary fellowship in a university for the investigation of a particular prob-

Extensive paper work is required to correlate data gathered by experts in petroleum research.



Exposure of test panels in this salt spray booth accelerates corrosion tests on metals and finishes.

lem, it was expected that the solution would benefit the manufacturer and ultimately the public (28)

In 1910, Andrew W Mellon and Richard B Mellon asked Dr Duncan to put his plan into active operation at the University of Pittsburgh (29) Fostered by the generous Mellon endowment, the plan was successful and was placed on a permanent basis in 1913 Until 1927 the Institute remained a part of the University of Pittsburgh, at which time it was separately incorporated. Since then it has been managed by an executive staff responsible through the Director to its own board of trustees. The Institute cooperates with the University of Pittsburgh, and members of its staff may take graduate work in the university. However, the Fellows in Mellon Institute have the status of salaried workers.

During the fiscal year ending March 1, 1947, the expenditures for pure and applied research at Mellon Institute totalled $2,697,982. The staff consisted of 295 Fellows and their 280 Aids, 34 more Fellows and 16 more Aids than in the preceding year

Researchers obtain data to determine the effects of various cutting oils on machine tool operation.

The Institute was active on 80 industrially sponsored projects, of which six have been in progress for 30 years or more, 2 for 25 years or more, 9 for 15 years and 19 for 10 years It conducts research in the fields of pure chemistry and in chemical physics The Industrial Hygiene Foundation, a non-profit national association for advancing health in technology, operates under the Institute's auspices

Armour Research Foundation of Illinois Institute of Technology, located in Chicago, was founded in 1936 without endowment (30) It is a separate corporation although it reports to the President and the Board of Trustees of Illinois Institute of Technology Since its conception, Armour has been an entirely self-supporting organization, maintaining its own staff and facilities.

During the fiscal year ending August 31, 1947, the volume of sponsored research for industry and government at Armour Research Foundation amounted to $2,551,854, an increase of 34 6 per cent over the previous fiscal year Of the 105 active research projects on September 1, 1947, 39 were projects under government sponsorship and 66 were sponsored by industry The Foundation is organized in three operating divisions.

(a) The Research Division
(b) Magnetic Recording Division
(c) International Research Division

The latter division, recently organized to render research service to foreign governments and industries in foreign countries, has its headquarters in Mexico City

The Research Division has departments of Physics, Chemistry and Chemical Engineering, Metals, Ceramics and Minerals, Electrical Engineering, Applied Mechanics, Mechanical Engineering and Research Service

On September 1, 1947 the staff of Armour Research Foundation numbered 488, with 322 on the technical staff and 166 on the service staff A further analysis of the 322 members of the technical staff shows that 12 5 per cent were occupied with scientific and technical supervision, 59 per cent were research scientists and engineers and 28 5 per cent were classified as technical and scientific assistants

Midwest Research Institute in Kansas City was organized early in 1945 and recently completed its third year of operation as a non-profit, independent, research institution serving both industry and government (31) In addition to functioning as a research institute serving the industries of the United States, the Institute has a unique function as a regional research laboratory working toward the development of the natural resources of the central mid-western states. Although an independent organization, Midwest cooperates with educational and research groups, particularly in the region from the Mississippi River to the Rocky Mountains. Conducting industrial research for mid-continental industry, developing new uses for existing agricultural produce, and developing the resources of farm, forest, mines, and wells of the region are primary objectives.

The total research expenditures during the last fiscal year amounted to $450,000, demonstrating a remarkable growth in the three years of Midwest's existence. At the end of the fiscal year the staff numbered 100, of which

60 were technical personnel and 40 were non-technical. Midwest Research Institute is now conducting research in agricultural chemistry, organic chemistry, inorganic chemistry, physics and engineering mechanics At the present time there are 30 major research projects active, not including short-term investigations and advisory services to industry

The Southern Research Institute at Birmingham, Alabama, is a non-profit organization, founded in 1945, supported by private capital subscriptions and endowments, and making its services and facilities available to industry on a fee basis fully protecting the sponsor's interests The Institute is doing industrial research in plastics, applied chemistry, physics, metallurgy, engineering, food technology, biochemistry and organic chemistry

Research expenditures for the year of 1947 will exceed $300,000, an increase of about $100,000 over the previous year There are at present 40 active research investigations During October, 1947, the research efforts were distributed as follows 69 per cent in industrial contracts, 15 per cent for government agencies, 14 per cent in the biochemistry of disease and 2 per cent on Institute sponsored research

The organization of Southern Research Institute now consists of about 80 persons, of whom 48 are on the technical staff and 32 are on the service staff

The Southwest Research Institute, an endowed organization for scientific study founded by Tom Slick, was dedicated September 11, 1947, on the Essar Ranch, 7 miles from San Antonio

The new laboratory includes chemical and biological units, engineering departments, and a complete machine shop Further expansion of facilities is expected as soon as materials are available The second laboratory of the Institute, devoted to petroleum chemistry and technology, is expected to be located in Houston

Although barely started, Southwest already has enough business to keep its present laboratories operating at near capacity This expanding organization currently has a staff of 40

The Southwest Research Institute is the third and final part of a research organization which also embraces the Foundation of Applied Research, now working on agricultural and medical studies, and the Institute of Inventive Research, which aids inventors in developing their ideas.

Leading industrialists of California and the Pacific Northwest recently cooperated in the establishment of Stanford Research Institute, which is a non-profit organization designed to undertake any type of investigation needed by industry or government (32) It is equipped to study problems in business organization, industrial relations, personnel procedures and marketing, as well as to do technical research in physics, chemistry, engineering and biology.

Under the plan of the Stanford Research Institute, all companies, both large and small, may use the services of experts in a wide variety of fields to carry on independent research or to supplement their own activities.

While the organization is entirely separate from the University, it will, nevertheless, draw upon the University faculty in its work, in addition to having its own staff of technicians and scientists.

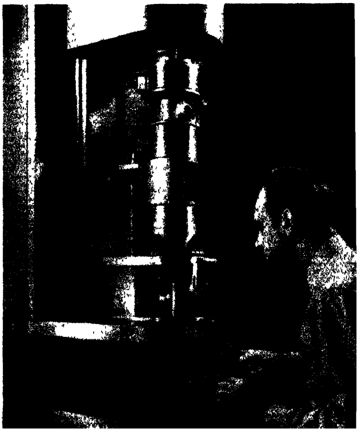
As one example of the engineering research and development organizations recently organized, Engineering Research Associates, Inc, in Minneapolis, might be cited At the close of the war, a group of scientists and engineers who had worked together in the Navy resolved to continue their research and development as a private enterprise Engineering Research Associates was incorporated January 8, 1946, supplementing the technical skills and training of the group with the management, fiscal organization, and facilities of the Northwestern Aeronautical Corporation

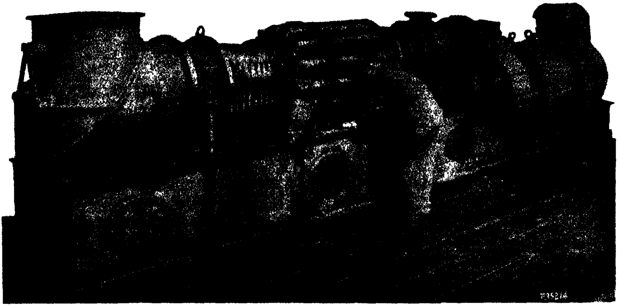
At the present time, Engineering Research Associates, with offices in Washington, D C., as well as in Minneapolis has a staff numbering 450, and is carrying out research and development work under contracts amounting to more than 3 million dollars annually

The primary objectives of Engineering Research Associates are in the fields of research and development. However, in order to insure that research and development will lead as far as possible toward public benefits, the organization undertakes certain limited production of equipment that gives a strong impetus to the practical solution of research and development problems

More than at any time in the past years, both industry and government are "farming out" their research problems to organizations of the type discussed above. It is becoming increasingly evident that the role of

Electron microscope is a research tool of great importance to many branches of modern industry.





Comprehensive research has resulted in a number of improvements on this 2,000 hp gas turbine unit.

the independent research organization will be a responsible one indeed To them industry looks for a substantial part of future industrial progress, a greater production of better and more products at reduced cost, opening new avenues of better living to all people

THE GOVERNMENT IN RESEARCH

Before World War II the United States Government paid about one-fifth of the nation's research costs, while industry, research organizations, universities and colleges financed the remainder. The war brought about a complete reversal of this situation as industry concentrated on production and the government spent greatly increased sums for the development of existing weapons and the discovery of new ones (34)

Since the war, governmental expenditures for research have dropped less than one-third while industry has increased from its 80 million dollars annual outlay for research during the war to a figure 6 to 8 times that amount. According to the Report of John R Steelman to the President, the government spent approximately 625 million dollars for research in the fiscal year 1947, exclusive of the atomic energy budget. Today there is little difference between the annual expenditures for research by government and by industry Steelman estimated research expenditures by industry at 450 million dollars, but others feel that the total is probably higher and might reach 600 million or possibly even 700 million dollars. Whatever the relative expenditures may be, it is evident that the Federal government has greatly increased its expenditures for basic scientific knowledge and the application of that knowledge, and that these expenditures are likely to continue high.

The government owns and operates research facilities valued at approximately 1.5 billion dollars, not including atomic energy development and production projects which probably double that figure. Thirty thousand scientists are now employed directly by the government and there are some 60 agencies which have distributed projects through all forty-eight states (35, 36).

Mr Steelman, in Vol II of *Science and Public Policy*, gives the Federal research expenditures, by agency, for the fiscal year 1947 as follows:

Navy Department	$262,000,000
War Department	237,000,000
Agriculture Department .. .	31,328,000
Interior Department . . .	30,358,000
Natl Advisory Comm for Aeronautics	27,000,000
Federal Security Agency	13,236,000
Commerce Department	10,494,000
Federal Loan Agency (R F C) ..	4,699,000
Tennessee Valley Authority	3,654,000
Veteran's Administration	2,523,000
Federal Works Agency	822,000
Smithsonian Institution	309,000
Treasury Department	220,000
Federal Communications Commission .	200,000
Maritime Commission	87,000

It is estimated that, over-all, 570 million of the 625 million dollars spent by government was used for applied research and development. Further, it is estimated that 465 million out of 500 million dollars spent by military agencies was for applied research and development.

Of the 625 million dollars spent on research, government owned laboratories did only about 200 million dollars of the work. The remainder was done by industrial laboratories, by research organizations and by universities and colleges Merely directing the program of government research has become a major operation, yet it is expected that the federal budget for research will be increased by at least two-thirds and possibly doubled within the next ten years.

Whenever private industry is unlikely or unable to pursue research urgently required in the nation's interest on an adequate scale, the Federal government and the State governments must take the responsibility. For example, prior to the war, research and development in agriculture consumed a large part of the research budget since individual farmers cannot afford to do research, yet the improvement of their methods and the search for new and basic scientific information in agriculture is vital to the nation's interest In the 1946 report of the Administrator of Agricultural Research it is stated that from a total investment of 10 million dollars in research on hybrid corn, the nation is now collecting annual dividends of at least three-quarters of a billion dollars Research on small grains by Federal and State laboratories is believed to have added half a billion dollars each year to the national wealth An investment of less than 1 million dollars in sugar cane research has increased the annual value of the sugar cane crop by more than 20 million dollars

In addition to research for the development of the nation's basic industries, for public health, for public safety, for the maintenance of adequate and reliable industrial technical standards, and for the development of precision scientific standards, the government now has the responsibility of supporting basic and applied research necessary to maintain our military security The international situation since the close of the war has necessitated the continuation of research in this direction

It is generally agreed that authority granted by Congress to the various departments and agencies is sufficient for the establishment of a sound research and development program A large part of the funds granted under this authority are now used to sponsor research in industrial or university laboratories, and such support will likely be expanded in the future.

Of Government research and development outlays during the war 83 per cent were for the military agencies The percentage remains about the same since the war During the war an emotional factor welded science and the armed forces into a victorious team Now the emotional factor, although not gone, is considerably lessened even though the percentage of government funds being spent for military research and development has remained about the same This is the problem with which the military agencies, much more enlightened and recognizing for the first time the absolute necessity for scientific research, are faced

Research and development units in the Army, Navy, and Air Force are not new things, but they are new, *big* things. Branches of the military have a new awareness of the necessity for research and development Such an awareness is made evident by their research programs and their determination to push those programs to completion Examples of this attitude may be seen in talks delivered before the Engineering College Research Council meeting in Washington in November, 1947, by Admiral Paul P. Lee, Chief of the Office of Naval Research; General H S Aurand, Research and Development Director of the Army; General L. C. Craigie, Research and Development Director of the Air Force; and, Dr. L. R. Hafsted, Executive Secretary of the Research and Development Board, National Military Establishment. In the words of Admiral Lee:

> "The war demonstrated most forcefully that the security of the United States is, to a very large degree, dependent upon our national scientific strength It is demonstrated that from purely basic research studies comes knowledge which can have a profound effect upon the conduct of war It is demonstrated that the civilian scientist and the man in uniform must work together if they are to apply our scientific knowledge to problems of national security"

Admiral Lee stated that the Navy has under contract "something over 600 research projects in about 100 universities and non profit laboratories By the end of this fiscal year we will have obligated over 50 million dollars for the support of this program We have planned to stabilize it at an annual expenditure level of 22 million dollars"

General Aurand stated that, under the direction of the Research and Development Division of the Army, "the Technical Services have at present contracted for 605 basic research investigations, roughly 10 per cent of which are being carried on by universities and colleges"

General Craigie said "At present, there are 54 universities engaged in research and development work for the Air Forces, working under 242 contracts These contracts cover research projects for the 12 different laboratories of the Air Materiel Command, and represent more than 10 per cent of the 1947 research and development funds".

The National Research and Development Board, represented by Dr Hafsted at the Engineering College Research Council conference, is a new organization, but it is actually an outgrowth of the Joint Research and Development Board, chartered during the war, established to avoid duplication of efforts

John R Steelman states in his Report to the President

> "it is vital that the funds for basic support of research be administered with the advice of an imaginative group of scientists" Here Steelman is alluding to the National Science Foundation Congress passed, but President Truman disapproved, a bill for the establishment of such a foundation during the 80th Congress There was, and is, controversy on the advisability of creating such an organization In his Memorandum of Disapproval, dated August 6, 1947, the President gave as his reason for disapproval the fact that the representative group of scientists was given full responsibility for the administration of the Foundation In his mes-

Reduction gear of axial flow jet engine is studied by subjecting it to simulated operating conditions.

sage the President said the role of the scientists should be "more appropriately one of advisory nature rather than one of full responsibility"

To quote the Steelman report on the matter of the Foundation.

> "It is . . recommended that the Congress be urged to establish at its next session a National Science Foundation within the Executive Office of the President and that the Foundation be authorized to spend $50 million in support of basic research its first year, with increasing amounts thereafter rising to an annual rate of at least 250 million dollars by 1957 No restriction should be placed on the fields of inquiry eligible for support
>
> "The National Science Foundation should be headed by a Director appointed by the President and assisted by a part time board of distinguished scientists and educators similarly appointed It is recommended that this advisory board be appointed half within the government and half without The Federal Government's share in the national science program makes it imperative that the Government's scientific agencies be represented in the planning of the basic research program
>
> "Moreover, a portion of the monies expended in support of basic research should take the form of grants from the Government's scientific bureaus and agencies themselves This is an important means of strengthening contacts between the government and private scientists, of keeping both groups informed of work in progress and of strengthening our total scientific effort
>
> "It is clear that a portion of the funds expended by the National Science Foundation should be used to strengthen the weaker, but promising, colleges and universities, and thus to increase our total scientific potential"

Later in his report Steelman states.

> "While the large role contemplated by the Federal Government will not necessarily be reflected in a comparable increase in federally-owned and operated facilities, considerable increase is desirable
>
> "Except in event of military emergency, it is unlikely that the Federal Government will have to finance the necessary expansion in industrial research facilities We should have a favorable climate for such expansion through tax incentives and other established methods, without making direct grants to industry"

When the bill for the National Science Foundation came up for debate in the 80th session of Congress it met some opposition from research men in industry and in private organizations (39, 40). The opposition was directed against the government's engaging in research and was based on the tenet that basic research could best be promoted by tax incentives to industry to induce them to finance fundamental scientific research.

Opposition to the passage of the bill was also based on the belief that greater diversity in research activities and freedom from political influence can be obtained only by encouraging private enterprise to furnish funds (41).

A bill introduced into the 80th Congress on February 5, 1947, would have made the Department of Commerce a clearing house for scientific and technical information This bill died in committee (42) It was not revived although certain portions of it reappeared in the National Science Foundation bill (43, 44)

It is very likely that legislation will be introduced in the next Congress to create a National Science Foundation, and it is not unlikely that necessary legislation to make the Foundation a reality will be enacted (45). It is also not unlikely that legislation will be re-introduced to create more extensive authority for the Department of Commerce to provide a technical service to industry.

RESEARCH IN THE INTERNATIONAL FIELD

Although United States firms have studied the products and resources of foreign countries in their own laboratories, seeking new sources of supply for raw materials and seeking new products for development, few of them have conducted scientific investigations in the foreign field It is true, of course, that many private companies have provided engineering and technical assistance on a consulting basis to foreign governments and industries, and in this manner a considerable amount of American technology has been exported

In 1942 the Corporacion para la Promocion del Intercambio of Argentina commissioned Armour Research Foundation, in Chicago, to conduct a study of Argentine industries for the purpose of.

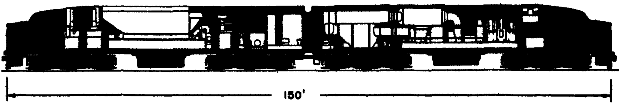
(a) Discovering ways in which scientific research can best be applied to the improvement of Argentine products already in production.

(b) Discovering ways in which scientific research can be undertaken to increase or create a demand for Argentine raw materials

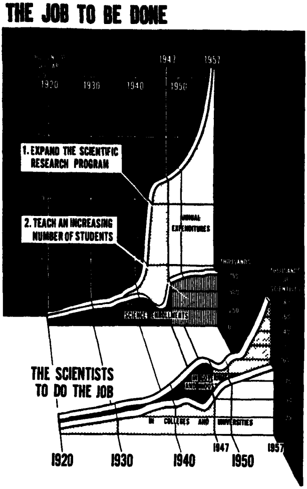
(c) Discovering ways in which certain Argentine raw materials can be used to alleviate shortages within the country.

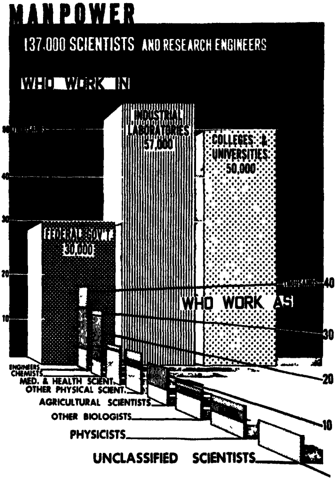
(d) Calling attention, where possible, to opportunities for applying known technology which might have been overlooked in the conduct of some Argentine industrial and agricultural operations (46).

Specifically studied were jute, hides and leather, minerals, dairy products, grains, chemicals, forest products, vegetable oils and fuel industries. The survey in many respects formed a pattern for similar studies which may be made for Argentina and other foreign coun-



Proposed arrangement of power plant and coal supply system in the gas turbine locomotive for with the Locomotive Development Committee of Bituminous Coal Research, Inc. The 4,000-hp coal-burning Allis-Chalmers gas turbine unit and its specially designed controls are scheduled to be ready for stationary tests in the fall of 1948. The completed locomotive is expected to be ready for operational tests early in 1949. Success of this coal-burning gas turbine will be a major advancement in railroading in view of the anticipated fuel economy.





tries and has led to the development of a number of helpful procedures

To help develop an orderly program of industrialization in certain fields of Mexican endeavor, and to promote the development of industrial technology in Mexico, Banco de Mexico undertook in 1945 a coordinated series of studies in fields associated with its diversified responsibilities and the national interest At the instigation of its Director General, Banco de Mexico requested Armour Research Foundation to make a technological audit of major areas of Mexican industrial activity, including coal, coke and other solid fuels and by-products, hides, leather, hard fibres and forest products in general, together with related industries and associated activities in agriculture, technical education, and research (47).

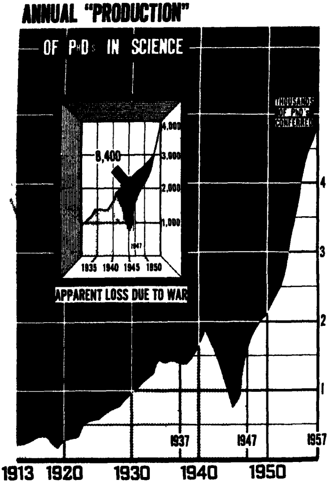
The basic survey was completed and published at the end of 1945, but numerous special research projects and laboratory investigations were continued well into 1946. In April of 1947, Banco de Mexico arranged for a new and expanded program. Projects now in progress include: evaluation of a packing house by-products industry in Mexico, a comprehensive study of fats and oils native to Mexico as raw materials for both new and established industries, evaluation of fluorspar deposits with a view toward their beneficiation, and the stabilization and nutritional improvement of the *tortilla masa.*

Countries of this hemisphere in Central and South America are becoming more conscious of the essential role that technology and research can play in the improvement of living standards for their peoples, in the stimulation of industrialization, and in the furthering of the national economy (48) Fortunately, this view is beginning to be shared by leaders of government, industry and banking everywhere

Financial and government leaders in the United States are also recognizing that scientific knowledge, research skills, and technological know-how form an important export commodity to assure a continued supply of raw materials for our indusrty, to maintain an active foreign trade, to provide for hemispherical security and to increase the standard of living for our country

THE MANAGEMENT OF RESEARCH

Research management and organization have their own peculiar and characteristic problems (50, 51). That this field of management is attracting great interest at this time is verified by the several conferences on research management held during the year, and by the great interest in graduate courses and seminars on the subject.



ANNUAL "PRODUCTION" OF PHD'S IN SCIENCE

The Engineering College Research Council held a well attended three-day meeting in Minneapolis in June of 1947 (52) Great interest was shown by a large attendance of industrial, university and government representatives. Proceedings of this conference, as well as the previous one held under the same auspices in 1946, are available in booklet form.

Pennsylvania State College conducted a conference on Research Management in October of 1947, again very well attended by numerous representatives of industrial laboratories, universities and government research agencies Proceedings of the Conference will be available early this year.

The Industrial Research Institute regularly holds two or more conferences each year to consider the many problems connected with operation of research laboratories in industry.

Well-attended and interest-filled graduate courses and seminars on research management, pioneered by New York University, have been continued at that institution, and have been conducted at Illinois Institute of Technology and at Pennsylvania State College.

Such conferences have emphasized the fact that management of research cannot be fitted into a definite pattern even to the extent possible in most fields of management Each laboratory with its peculiar conditions of personnel, objectives and background presents a unique situation taxing the utmost skill, ingenuity and understanding on the part of its management to secure maximum creative productiveness. The growing shortage of technical manpower will make even more difficult the problems of management, since the skills, abilities, experience and know-how of able scientists must be spread even thinner over the rapidly multiplying and increasingly complex problems brought to the laboratory for solution.

RESEARCH IN MANAGEMENT

The place of research in management is receiving an increasing amount of attention and interest Dr Raymond Stevens, Vice President of Arthur D Little, Inc, pointed out before the June, 1947, meeting of the Industrial Research Institute that it was not uncommon a short time ago for management to be divided into three parts production, sales, and finance, with the head of the organization either a production, sales or financial man, depending upon his force of personality or family inheritance The three parts were the complete triumvirate of management

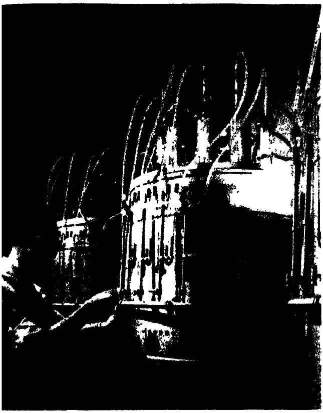
"Research is now being accepted as a portion of this policy-and-decision-making group", Dr. Stevens continues "Today's research director may have the same title as that of thirty years ago, but he has much greater responsibility".

There is a decided trend to make the chief research officer a part of top-management, frequently with the title of Vice President, and to depend on him to take a prominent part in policy decisions Dr. Stevens suggests that the research director must

(a) Know and help formulate the over-all future policy of the company
(b) Plan for products and processes leading in the right direction.
(c) Not only explore scientific and technical areas but must examine markets, patents, costs and competition
(d) Be as thorough in his economic as in his technical examination of a new development
(e) Create and prove new products and processes that will reach an attractive market, be free of patent or other important restriction, meet competition, and make a profit.

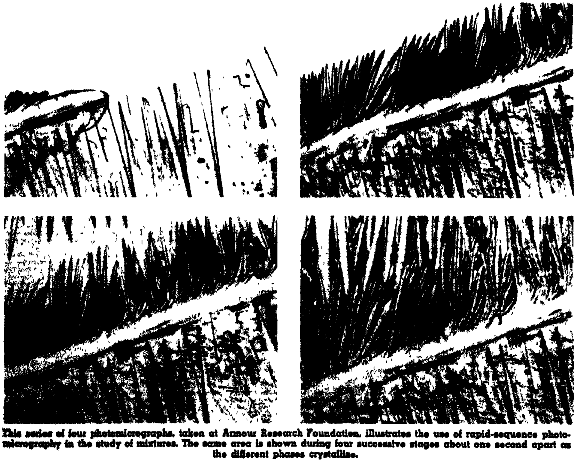
Maurice Holland, Industrial Research Adviser, reports a recent survey on *What Management Expects of Research* and lists the following in the order rated by the management of several companies:

(a) New Products.
(b) Maintenance of competitive technical position.
(c) Cutting production costs.
(d) Sales volume and net profit on new processes and products.
(e) Serve production through development of new and improved processes.
(f) Be on the level or in advance of the best managed laboratories of the leading companies.



As research advances, more complex and expensive experimental equipment becomes necessary.

Unique design features this new development and testing laboratory of the Benjamin Electric Mfg. Co.



This series of four photomicrographs, taken at Armour Research Foundation, illustrates the use of rapid-sequence photomicrography in the study of mixtures. The same area is shown during four successive stages about one second apart as the different phases crystallize.

(g) Operate like other departments of the company, not as "prima donnas" of special privilege.
(h) Serve the chief executive in long range planning
(i) Demonstrate the dollar value of research.
(j) Assist sales with technical service.

Thus research in industry, and its place in the corporate structure, is becoming more than a mere *fact-finding unit* concerned solely with scientific exploration (54). As the fountain head of new products, proccesses, and developments, research has an important place in determining long-range industrial policy and in providing a needed service to production, sales, and distribution as well as an advisory service to financial management Industrial recognition of this new role is unmistakable.

Illustrative material for this section was provided by Merck & Co. Inc, Johns-Manville Corp, Battelle Memorial Institute, Armour Research Foundation, Midwest Research Institute, Mellon Institute, Southern Research Institute, Gulf Oil Corp, General Motors Corp, Westinghouse Electric Corp, Allis-Chalmers Mfg Co, General Electric Co, Benjamin Electric Mfg. Co.

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CHAPTER III

AIRCONDITIONING, REFRIGERATION, HEATING

by DAVID L. FISKE

In retrospect, the early post-war period for refrigeration, air conditioning and heating will probably be regarded as one of marked technical progress. These advances are not due to the developments in the last few years, but rather to those which took place during the war. As in many industries, great impetus to peacetime practices has resulted from wartime discoveries This is especially marked in the field of refrigeration

The full impact of these wartime changes will not be realized for some time to come Indeed, the greatest concern of those at present engaged in these fields remains less with technical progress than with reconversion problems of a purely business nature. Demand has been greatly stimulated over that of the pre-war period, and as elsewhere materials have been in short supply. For this reason, full advantage has not been taken of the new products that are both feasible and anticipated

In the following brief survey, it is impossible to mention all the developments of the war and post-war periods, many of which have remained secret. This is at best an overall survey, intended only to point out the most significant trends.

REFRIGERATION

The demand for all refrigeration items has increased greatly since the war, justifying the claim that this is a billion dollar industry The full extent of the new demand cannot be measured since the largest single item of manufacture, domestic refrigerators, is still short of meeting current needs, along with other durable consumer items such as automobiles.

In the field of commercial refrigeration systems, it is also doubtful whether supply equals demand, but statis-

TABLE I

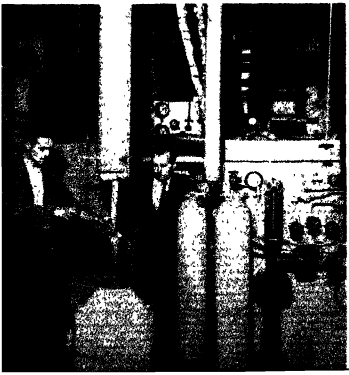
REFRIGERATING AND AIR CONDITIONING EQUIPMENT MANUFACTURED IN THIRD QUARTER OF 1947, U S. A.

Product	*Total*		*Domestic*		*Export*	
	Number	*Value* (1000's dollars)*	*Number*	*Value* (1000's dollars)*	*Number*	*Value* (1000's dollars)*
Condensing units	293,238	20,994	275,229	19,033	18,009	1,961
Ammonia refrigerants	419	560	370	510	49	49
Refrigerants except ammonia	292,819	20,434	274,859	18,522	17,960	1,911
Air cooled	283,972	16,808	266,572	15,210	17,400	1,598
Open type	117,940	10,456	102,391	8,944	15,549	1,512
Hermetic type	166,032	6,352	164,181	6,266	1,851	85
Water cooled	8,847	3,625	8,287	3,311	560	313
Compressors and compressor units	159,242	8,916	151,001	7,946	8,241	970
Ammonia refrigerants	970	2,260	762	1,803	208	457
Refrigerants except ammonia	158,272	6,656	150,239	6,142	8,033	513
Centrifugal refrigeration machines	84	2,086	63	1,631	21	455
Heat exchanger equipment	—	11,946	—	11,056	—	889
Evaporative condensers	1,556	1,924	1,407	1,768	149	156
Unit coolers	33,227	4,797	29,864	4,356	3,363	440
Air conditioning	4,032	1,492	3,476	1,354	556	138
Refrigeration	29,195	3,304	26,388	3,002	2,807	302
Other heat exchanger equipment	—	5,224	—	4,930	—	293
Self-contained air conditioning units	15,854	9,094	14,670	8,454	1,184	639
Room type	7,927	1,818	7,021	1,483	906	335
Other than room type	7,927	7,275	7,649	6,971	278	304
Ice making machines	1,866	627	1,722	489	144	137

tics are at least available to show a marked growth. Table I is a typical running summary of manufacturing activity in refrigerating machinery for commercial and air conditioning purposes. Even the availability of such information from the Federal Census Bureau has improved. This information, in much less detail, was formerly available only every second year, but it is now published quarterly. In this table, the total manufacture of 53 million dollars worth of equipment in one quarter compares with the total 1937 output of the same products of less than 100 million dollars (1).

A CO_2 fire extinguisher is checked in the all-weather chamber of the Equipment Laboratory at Wright Field, Ohio, after being subjected to a temperature of —85 deg. F. for 72 hours.

The new Ohio State University laboratory has facilities for exploring temperatures near absolute zero.



Low Temperatures

A marked change has taken place in the experience of refrigerating engineers with temperatures below —40 deg. F., which was the minimum commonly employed before the war. The new art of low temperatures arose in part from the need for oxygen for various purposes, including high altitude bombing, as well as from work with test chambers for pilots and equipment to be used at the low temperatures encountered at high altitudes (2). Other industrial and laboratory needs posed similar problems, and a variety of systems came into use, making —100 deg. F. a fairly familiar temperature zone for refrigeration spaces; —250 deg. F. and lower became not uncommon in parts of processes or mechanical systems.

In a widely publicized laboratory-hanger for the Army Air Forces, a temperature of —70 deg. F. was provided in a room large enough to hold modern air liners, roughly 200 by 250 by 70 ft (3). In conjunction with a new method of food storage and shipment, one laboratory held a temperature of —160 deg. F. for long periods in a room about 30 by 16 by 10 ft. Laboratory test rooms of normal size, with temperatures approaching —100 deg. F., were built in various places, as were test rooms for accommodating trucks and other automotive equipment under conditions to be expected in polar warfare (4). Among other interesting laboratories was one for testing human reactions under conditions of extreme cold (5).

Refrigerator manufacturers have produced, incidental to low temperature work, standard cabinets and containers which provide temperatures down to —100 deg. F. or lower (6). These machines can be purchased much like household refrigerators, although the cost of operation is much higher than for refrigerators used for higher temperatures. Other more or less standard mechanical units have been produced for refrigerating altitude test chambers, where the problem is not only to produce low temperatures, but very wide and rapid changes of temperature, as well as barometric pressure (6). Tremendous wind tunnels have also been built for low temperature air researches, such as the one at Cleveland (7).

Refrigeration was used during the war at new low levels of temperature in the production of oils and artificial rubber. It was likewise brought into play in the area of lyophilization, or drying from the frozen state, a process first developed for laboratory uses and biologicals (8). During the war, this process was employed on a large scale for penicillin plants, calling for large ammonia compressors (9).

Low temperature developments were aided by the availability of a new refrigerant, F-22, with characteristics similar to those of F-12, including low back-pressure for low temperatures. Systems using both these fluids were developed. Ammonia and ethylene were also used.

The year 1944 marked the spectacular conclusion to a large refrigeration project when three large tanks of liquid fuel gas, at a temperature of below —150 deg. F. were responsible for a disastrous fire which destroyed a considerable area in Cleveland.

Low Side Developments

In the area of mechanical improvements, as apart from any particular use of refrigeration itself, the chief developments have perhaps been on the so-called "low side". Various technical developments have aimed at perfecting this part of the system, including improved oils for systems of all temperatures, and means of controlling the behavior of the oil within any system (10) A related interest has been evidenced for the improvement of drying by means of moisture removal devices An effort has been made to improve the operation of systems, especially to prevent corrosion (11) The manufacturers of Freon refrigerants have, meanwhile, emphasized improvements in their processes for providing a drier gas

New devices have appeared to solve the old problem of defrosting. The first one to attract attention was a thermo-bank or liquid storage arrangement. Another controls the cyclical admission of heat to the evaporator in response to the amount of frost built up on surfaces The idea of removing the cooling surface to an antechamber, where it may be defrosted, has been introduced (4)

Some experimentation has been conducted with systems where the refrigerant is not only used flooded but is pumped through the vessels which provide the evaporating surface The development of liquid injectors to replace simple expansion valves has attracted the attention of all refrigeration engineers (12) Capillary tubes are now widely used (13). Knowledge of the design of refrigerant-containing vessels in relation to heat transfer has been improved by experimental data by Katz and others (14)

The use of low temperatures has made new designs for thermal expansion valves essential Due to the flattening of the pressure-temperature curve at low temperatures, the ordinary gas bulb operating in response to a few degrees of suction superheat fails to provide a suitable range of open-shut responses in terms of temperature A differential value using two bulb fluids has been adopted.

There has been a corresponding improvement in the area of suction pressure valves in order to make control responsive to load temperature New studies have also appeared on humidity in refrigerated spaces, and on its control with conventional equipment (15)

Insulation

Not the least remarkable of many areas of progress is that of low temperature insulation. The intensified wartime demand acted as a practical introduction to many new substances which were more or less experimental a few years before. The choice of new insulants was originally stimulated by the domestic refrigerator, where lower conductivity offered marked savings in door and wall thickness. Much ingenuity has been used in designing these parts. War needs also brought into use more expensive materials than had been employed previously, because of the correspondingly larger volume that could be offered to the buyer. Lighter materials were at a premium because weight savings resulted in lower freight costs.

Among new materials, several were of a wood or other organic base, others of a mineral wool material. Shredded bark, cork and rock cork continued to be popular. Hair products, finely spun glass, foam glass and expanded rubber are well known. Aerogel is said to show extraordinarily low conductivity Loosely attached, thin layers of celluloid film have been used, as has the new substance, polystyrene

Research has revealed the conductivity and other characteristics at very low temperatures of all insulating materials in some detail (16, 17) Studies by C. F Kayan have greatly increased technical understanding of the behavior of heat in structures where there is not only a thickness of insulating material but a conducting member (18)

On the high side of the refrigerating system, perhaps the most outstanding development has been a hermetically sealed compressor weighing about five tons. This is an adaptation of an idea, long applied to domestic refrigerators, of preventing the escape of refrigerant gas by enclosing the motor inside the gas system. This equipment will probably be more extensively developed.

Frozen Foods and Other Applications

Frozen retail packaged foods went through a considerable boom at the end of the war, although it later suffered a commercial setback. But the technical field has continued to attract much study, with many improvements yet to be achieved. The subject has been greatly served by a new edition of Tressler's outstanding book (19).

Few pieces of refrigeration equipment have had as much technical attention as the home freezer, or deep freeze The construction and operation of this device have been widely publicized, and a standardization project undertaken (20) A marked growth in the number and size of locker plants during and since the war has been one of the reasons for the heavy demand for refrigerating devices. While only about 2 per cent of the foods consumed today are frozen, the magnitude of machines and devices required to produce, transport, store and display this material bulks large.

The whole technique of freezing has been revolutionized in the last few years, but many new schemes will be introduced in the near future. Various forms of tunnel and contact freezers have been built for freezing fruits, vegetables, meats and fish, in and out of the package The enormous overseas shipment of frozen meats for the armed forces not only strained the freezing capacity of producers to the utmost, but has compelled shippers to use all vessels and railroad equipment available, some of it never intended for use with a frozen load.

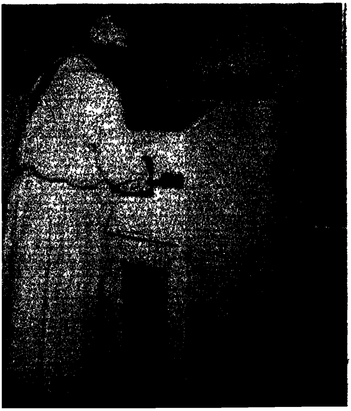
This experience, and the large fleet of merchant vessels built during the war, brought marine refrigeration into being as a fully-grown department of the general science of refrigeration. A committee of engineers who assisted in this development have written a general standard for marine refrigeration practice (21). A related development was seen in the field of Naval refrigeration, calling for many special applications, in addition to the supply of refrigerated services and foods to personnel.

The use of refrigeration by the Army in small portable units posed new problems for the manufacturing industry and new experiences for the users. Not the least of the war influences was the training of a host of service mechanics and others, who for the first time became familiar with cooling systems and who later carried back their experiences into industry.

Developments in the field of refrigerated foods have included the improvement of storage practices, odor removal in cold rooms, and use of circulated air as a means of preventing food decay (22). The growing practice of packaging fresh fruits and vegetables and selling them under refrigerated conditions tends to reduce the tremendous spoilage which has always been experienced in this work. (23). Air control in cold storage seems to be a developing practice, stemming from air flow practices in comfort cooling systems. Similar to this is the increasing use of unit coolers in cold rooms to replace *still air* coils.

Workmen install inner lining breaker strips on 30 cu. ft. models of food freezers.

Refrigerating equipment plays an important role in preserving the potency of biologicals.



For large cold storage plants using ammonia, a new kind of finned surface, consisting of aluminum disks cast on steel pipe, has provided the only advance in low side surface in many years. This product, an invention of George B. Bright, has resulted in great savings in cold storage space and building materials (24).

The last two years have produced three or four tradenamed refrigerated truck bodies, all operating from small refrigerating units driven by gasoline engines. The operation of fleets of refrigerated trucks promises to become a common practice in the near future. Under the sponsorship of D. F. Fisher of the Department of Agriculture, great improvements have been introduced in railway refrigerator cars.

Indicative of the mature state of the art of refrigeration was the establishment in 1946 of the first complete indexing service for all refrigerating literature, through the periodical, *Refrigeration Abstracts,* published by Professor Mack Tucker of the University of Tennessee, it is published quarterly, with an annual index.

Remarkable advances have been made in the application of refrigeration processes to various phases of public health and medicine. The method for treating certain disorders, notably shock, by temporarily refrigerating the whole body became known some years ago. Dr. Temple Fay has held body temperature as low as 78 deg. F. for long periods. Further experiments have involved freezing certain body members incidental to surgery, for patients unable to take anaesthetics.

Domestic Refrigerators

Efforts have continued toward reducing the weight and physical size of refrigerating units in domestic refrigerators, thus saving material and lowering cost. Today's 8 cu ft refrigerator takes up no more floor space than older 6 cu ft models.

Motors are of the same general design as before the war. A single-phase induction motor with split-phase starting controlled by an external relay is commonly used. The relay cuts out the split phase when the motor approaches full speed, giving overload as well as over- and under-voltage protection. Motor size runs 1/8 hp for units up to 7 cu ft and 1/6 hp for larger sized refrigerators. Vinyl-formaldehyde resin, which is unaffected by oil or refrigerant and incapable of retaining or developing moisture, is replacing cotton as an electric insulation.

Compressor changes have been marked. Greater bearing area and larger wrist pins are common. In sealed units, three electrical leads and two copper tubes are the only connections required between the mechanism within the cylinder and component elements outside.

A combination refrigerator and home freezer has become popular, with 1.0 to 1.5 cu ft of freezer space and high humidity fresh food space built in. Each compartment usually has its own door, so that no air circulates between the two compartments. For the two levels of temperature, two refrigerating systems are installed. In one make of refrigerator, the primary circuit has its evaporator in the freezer, consisting of aluminum tubing brazed to an aluminum shell. The secondary refrigerating system uses copper tubing and a control valve. The tubing zigzags around the two sides and back of the fresh food space and has thermal contact with the rear of the primary evaporator. This enables the secondary system to pick up heat from the lower compartment and pass it to the primary evaporator. Thus the primary system compressor actually refrigerates the entire combination cabinet.

With a separate control valve on the secondary system, enough evaporator space is available to hold high humidity, by virtue of high evaporator temperature, just above freezing at all times. This means that defrosting is never needed. Defrosting of the freezer section is infrequent. Completely insulated from the fresh food section, the freezer acquires frost only when the door is open. Condensation on the wall of the lower compartment runs out through a drain to a pan where it is evaporated.

AIR CONDITIONING

Reconversion from the war effort finds air conditioning lagging behind refrigeration. The large demand for industrial and comfort air conditioning installations common from 1936 to 1941 has not been duplicated as yet in the post-war market. This is due to a variety of factors, perhaps the most important being the shortage of all industrial materials, particularly steel. Industrial purchasers have had more pressing needs for other machinery and services. There has been no decline in the popularity of air conditioning, but its peacetime expansion must wait upon the satisfaction of more basic needs.

The delayed post-war boom in air conditioning has been due also to the unexpected cost rise in the building industries, which has tended to postpone purchases of any but the most basic materials in all kinds of buildings.

Air conditioning, moreover, had received less publicity and technical impetus from the war than did refrigeration. This does not mean that it was not installed, nor that new uses for it were not found. Indeed, the initial building of war plants created an unparalleled demand for comfort cooling in factories, which may eventually lead to its universal application. However, with the advance of the war, demand for refrigerating machinery for other purposes became so great that it was not possible to expand its use for comfort purposes. For these reasons, it is difficult to evaluate the final effect of the war on air conditioning.

The new laboratory of the American Society of Heating and Ventilating Engineers in Cleveland is constantly promoting new developments in its field. Tests are in progress to determine the physiological *shock effect* of summer air conditioning, resistance to high temperature, ventilation needs for a hygienically safe industrial atmosphere, performance of air-cleaning devices, etc. Other research projects are concerned with the low pressure properties of water and the friction flow of air in tubes and ducts.

Disinfection by Conditioning

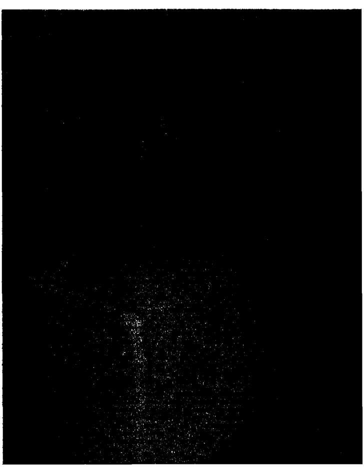
The concept of air disinfection by the use of glycol vapors has become well established. Field trials by Edward Bigg, H. H. Jennings and F. C. W. Olson have shown a reduction in airborne infection by the addition of bacterial concentrations of propylene or triethylene glycol vapors (25).

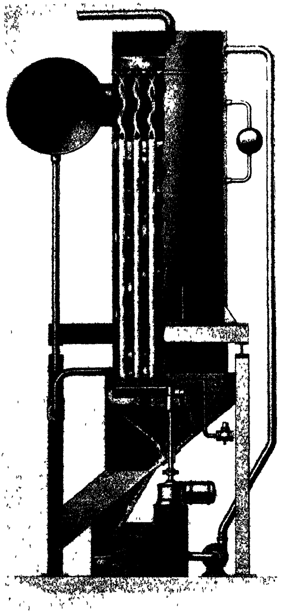
A school 360 ft wide and 600 ft long, with a capacity of 3.5 million cu ft, has been equipped for distributing triethylene glycol vapor. Ductwork constructed of 3 ft lengths of laminated asbestos was used. Uniformly spaced on 9 ft centers, ceramic venturi-type openings delivered glycolized air to the upper portions of the rooms from the above mentioned ducts in which the air moved at relatively high static pressure.

Individual units for delivering glycol vapors were used in barracks, where experiments were conducted to determine the effect of vapor on incidence of respiratory infection. A reduction of 46.2 per cent in disease incidence resulted from the use of this vaporized air in sleeping quarters. Still another installation of general interest has been recently completed in a large bank (26).

Dust collection for industrial application has been one of the more active phases of air conditioning. One system, employing an electrostatic field in which objects

Testing a new model home freezer at the factory.





Section through machine for the automatic production of of ice cubes.

with like charges repel and unlike attract, has been developed for domestic uses. The field is created by seven highly-charged tungsten wires and eight grounded aluminum tubes, alternately spaced. Air then passes a dust-collecting cell, consisting of a large number of aluminum plates, alternately charging negative and positive. High voltage direct current for the unit is produced from standard current by an assembly of electronic tubes.

Another system of air cleaning employs a filter unit consisting of a special paper mat for use with electrostatic type collectors. Still another has a filter made of chemically treated hair. Once fully charged, the filter is discharged.

Dehumidification

Great steps have been taken in the field of dehumidification, due in part to the location of much war material in humid areas. The Navy found that metals rust and tarnish when relative humidity exceeds 25 per cent. Mold and mildew begin at relative humidities over 70 per cent with temperatures as low as 80 deg. F. Hydroscopic materials, such as foods and chemicals, spoil and become useless at relative humidities as low as 50 per cent, depending upon the material and its moisture-retaining qualities.

Operating costs for dehumidification systems have been cited as 1/20 of one per cent of the value of the material handled, with an investment of three per cent of the same value A major airline found that with less than a 2,000 dollar investment it could save more than 7,000 dollars a year on replacement of radio parts.

Dehumidification employs two methods: (a) refrigeration, and (b) "sorbents". Refrigeration condenses out moisture, cools the air to the desired dewpoint, and then reheats it to the temperature necessary to maintain any desired relative humidity. This may be somewhat costly. Sorbents, absorbents or adsorbents, on the other hand, possess advantages where the dewpoint is below 65 deg. and relative humidity is lower than 50 per cent.

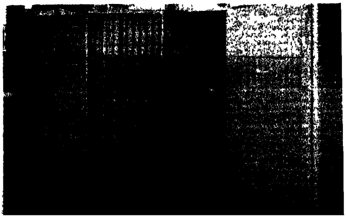
Such dehumidification can be accomplished by static or dynamic means Static treatment consists of a container of adsorbent material placed inside the package or enclosure to be treated. Dynamic dehumidification circulates air through adsorbent material, which is automatically reactivated to maintain continuous operation at constant humidity within the treated space. Liquid or solid materials may be used (27).

Psychometry and Design

Considerable effort is being made to improve the design of systems by calculation of coil surface areas on the basis of exact weather or psychometric data Surface area is determined as a function of the mean difference between total heat of air and total heat corresponding to saturation at surface temperature, permitting a graphical solution. This applies only where a portion of the surface is in a dry condition (28). Systematic studies of related theory appear in an excellent book on air conditioning analysis by William Goodman (29).

The measurement of relative humidity continues to be difficult. There has been some discussion of a dew point method of measurement. It is difficult to find apparatus satisfactory for air conditioning and refrigerating use. More exact data to assist measurements below the freezing point have been cited above (30). An electronic instrument has been proposed for measuring the dew point in the fog zone. It uses the incidence and reflection of light rays on a highly polished mirror in and out of the fog zone.

Servicing dust collector plates in an electronic air filter.



Problems Involving Water

Water treatment is an important phase of air conditioning. Most natural waters corrode metal and deposit scale. If these tendencies are not counteracted, they increase as the water dissolves impurities in the air. Evaporation of water also leaves dissolved salts that contribute to the scale problem Corrosion can be inhibited by the use of an alkaline substance to counteract continual absorption of acid gases from the air, with simultaneous use of a chemical inhibitor such as sodium chromate to protect metal surfaces (31).

A small tractor and a large fuel servicing truck emerge from test refrigerator.

Centrifugal propane gas compressor in oil refrigerating plant.

To prevent scale formation in cooling towers and evaporative condensers in hard water areas, common practice is to use surface active materials, such as certain polyphosphates, for increasing the solubility of the scale-forming salts. Blow-down from the cooling water circuit is regulated to limit concentration of salts. Make-up water to the system may be treated by means of an ion exchange softener.

Inhibition of organic growth from slime and algae is accomplished by treating water with germicidal agents such as chlorinated phenols, fed continuously in small amounts, or intermittently in heavier doses. The germicide must be non-toxic, and non-volatile chromate used for the prevention of corrosion fulfills these requirements

Machinery and Controls

The current trend in equipment for large air conditioning installations is toward the centrifugal compressor, in capacities from 100 to 2,600 tons. All manufacturers stress the steam turbine as a drive for centrifugal compressors, permitting the elimination of step gears, which are required with electric motors. In installations of large tonnage, the added cost of the cooling tower to handle the turbine condenser is reported to be small in comparison with the total air conditioning installation.

A five-stage propane compressor, turbine-driven, has been built for the Atlantic Refining Company, with a capacity of 1,955 cu ft per min. from a 21 lb per sq in absolute suction pressure at 9,360 rpm. Two similar units for the Standard Oil Company of California handle sulphur dioxide, for use in the removal of heat reaction in petroleum processing.

New material has been presented on power needs for air conditioning systems in various types of establishments. Figures for variation of power consumption during the cooling season and its relation to degree days above 65 deg. F., are now available.

In the area of small air conditioning installations there is little new to report. Like the domestic refrigerator, the small comfort cooler has been regarded, for wartime purposes, as a luxury. However, it is now coming back into production. Many of the items mentioned elsewhere in this review will be available for improvement; that is, new and improved materials, controls, electric motor equipment, as well as a variety of redesigned compressors, including the new hermetic models.

In the area of conditioning controls, a series of exceptional studies has been published by Walter Grant, permitting new economies of operation not previously possible, through the improved use of cooling surface (33). Further interest has been evinced on the subject of zoning, which provides a means of reducing the load on any system. This field had undergone considerable development before the war. Zoning is the division of a heating or conditioning system into sections to permit devices to operate independently. ***Exposure zoning*** accounts for the variations in heat losses or gains from wind and sun effect. ***Internal zoning*** compensates for variations in people and lighting load. Five basic methods are: (a) use of separate heating or cooling equipment for each zone; (b) reheating or recooling: i.e., adding or subtracting heat from air already treated, (c) use of separate recirculation fans, in which a single system supplies conditioned air to two or more circulating fans, equipped with mixing dampers; (d) dual ducts using two supply ducts, each with air at different temperatures and employing mixing dampers at the outlets, and (e) volume dampers throttling the air to each zone or room by means of automatic volume dampers.

The best sources of technical data on air conditioning are the annual volumes of the ASHVE, and the Refrigerating Data Book (ASRE) (6).

HEATING

District Heating

The present high level of industrial production, which has placed such high demands on all industrial services, affects the central station heating company At the same time, the demand has been stimulated by the increased cost of operating and maintaining isolated systems. Steam sales have increased yearly, and promise to continue in the future.

A major problem of long standing in the heating field is the low load factor. As a means of correction and control and to make the demand less seasonal attempts are being made to increase the use of steam during the the summer months for comfort air conditioning (34). Purchased steam may be employed for this purpose in several ways, for absorption or jet machines, or for steam-driven compression systems of refrigeration.

Among 50 district steam companies reporting operating results for 1946, five had an annual load factor between 15.0 and 19.9 per cent; 28 firms reported 20.0 to 29.9 per cent; 16 firms had 30.0 to 39.9 per cent; and one had 43.0 per cent. A further means of meeting the situation has been proposed through the use of a single large, high-efficiency boiler on the annual base load, with smaller units to handle the prevailing seasonal load.

The National District Housing Association recently discussed heating costs, finding that a new plant now costs 100 per cent more to erect than in 1940, with operating expenses up 50 to 90 per cent. Production cost runs 67 to 77 cents per 1000 lb. in the case of larger companies. The highest selling rate reported was $1.30 per 1000 lb (34).

Research in this field continues. During the war, experiments were conducted on cantonment heating installations, including the subject of corrosion prevention (35). The use of amines for chemical treatment of steam is under study at the U. S. Bureau of Mines.

Central station heating is being advanced as a means for enabling coal to compete with other fuels in some of the new housing projects, as well as a means of smoke prevention (36). Meanwhile, the coal industry is investigating a better method of producing gas, with an eye to larger heating, cooking and air conditioning loads in homes and elsewhere (37).

Unit Heaters

Progress in the unit heater industry has been, in the main, an economic one, reflecting the increased demand shown by recent statistics. The utility of the device, in either the propeller or blower type, is high and its control by means of thermostats very satisfactory.

Radiant Heating

Radiant heating has been the most widely discussed popular phase of the heating field. Last year another conference on the subject was sponsored by the American Society of Heating and Ventilating Engineers at which design standards were discussed. Representatives of many trade groups are participating in a project for further study of this nature, breaking down the subject to· (a) heat distribution within and behind a radiation panel, (b) heat transfer between the panel and space; (c) comfort conditions; and (d) controls.

Much has been published on this subject. The heating and air conditioning contractors have issued a bulletin on the design and installation of radiant heating (38). The merits of various methods of locating panels has been discussed. (39). Investigations by Raber and Hutchinson concluded that irrespective of the kind of panel or the method of heating, area and temperature can be fixed in terms of the thermal characteristics of the structure. When a heat balance analysis has been completed, it is then possible, from a knowledge of the equilibrium room air temperature and the average temperature of the unheated room surfaces, to evaluate the required dissipation rate at a fixed temperature. Various conductance data for panels of common design were cited (40).

Further data on operating characteristics of panel heaters, compared with conventional tube radiators, have been made available recently from researches at the University of Illinois (41).

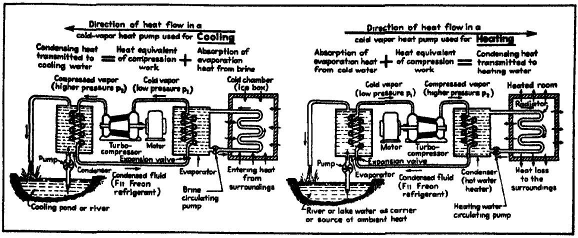
Recent practice in England is reported to favor a floor heating system using hot water in a surface of "dumb-bell" cross section, installed in duct spaces in the floor. With a mean water temperature of 160 deg. F., and an air temperature of 100 deg. F. in the sub-floor a floor surface temperature of 75 deg. F. results in heat emission of about 300 Btu per linear foot of surface, of which 270 reach the room (42).

A heating system using high-temperature hot water has been designed for a Florida paper mill, serving four buildings. A central heat exchanger receives plant steam for initially heating the water. The hot water for the individual plants enters individual exchangers through the coils of the radiant heating system in each building. Water on the main circuit returns for reheating to the central plant. Individual boiler circulating pumps have been provided for each area (43).

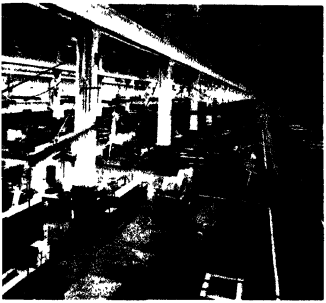
There has been some controversy about the merits of the closed and open panel heating systems. The closed system is more common with hot water flowing through embedded pipes. This provides only heating, but the open system permits air to be first warmed and then circulated, with other functions such as filtering being made possible (44).

Solar Heating and the Heat Pump

Solar heating has received much popular attention

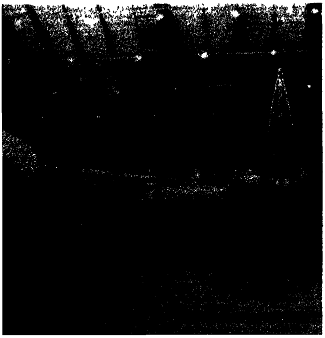

Direction of heat flow in a
cold-vapor heat pump used for Cooling
Condensing heat transmitted to cooling water
=
Heat equivalent of compression work
+
Absorption of evaporation heat from brine
Compressed vapor (higher pressure p_2)
Cold vapor (low pressure p_1)
Cold chamber (ice box)
Turbo-compressor
Motor
Expansion valve
Pump
Condenser
Condensed fluid (F11 Freon refrigerant)
Evaporator
Brine circulating pump
Entering heat from surroundings
Cooling pond or river
Direction of heat flow in a
cold vapor heat pump used for Heating
Absorption of evaporation heat from cold water
+
Heat equivalent of compression work
=
Condensing heat transmitted to heating water
Cold vapor (low pressure p_1)
Compressed vapor (higher pressure p_2)
Heated room
Radiator
Motor
Turbo-compressor
Expansion valve
Pump
Evaporator
Condensed fluid (F11 Freon refrigerant)
Condenser (hot water heater)
Heat loss to the surroundings
Heating water circulating pump
River or lake water as carrier or source of ambient heat

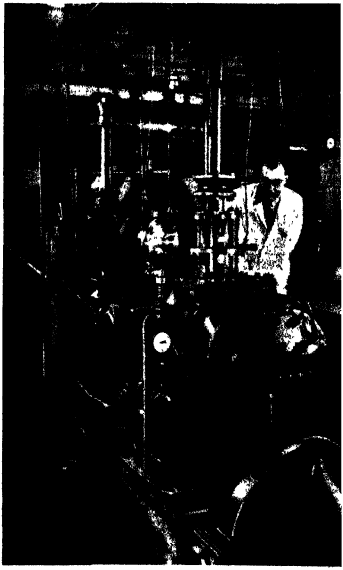
The heat pump principle: Illustration of operation in summer, at left: and in winter, at right.



Assembly floor for centrifugal compressors shows modernized manufacturing facilities.

Operation of aircraft and the performance of fuels, lubricants and machinery are tested at low temperatures.





Strobatic light enables engineers to test moving parts of compressors under actual operating conditions.

and has influenced the design of homes in some parts of the country (45).

The heat pump, a device common to both cooling and heating, has also been greatly publicized, with at least one complete technical book appearing on the subject

(46). In industry, pressure has been exerted by electric light companies which view this scheme as a possible means of increasing the demand for power, especially in areas of mild climate. The Southern Research Institute has been active in this field (47), as has the Edison Electric Institute (48, 49)

While the notion of using the heat-rejecting phase of the refrigerating system for heating purposes dates from the time of Kelvin, practice has still been limited to a few business and residential buildings. Economic justification rests in the use of one system to both heat and cool, depending on the season. A major obstacle has been to find a source of low-temperature heat in winter, and solution has been sought recently in the use of wells or other means of getting heat from the ground In the last two years, commercially designed units ready for home installation have appeared on the market Moreover, a heat pump phase has been introduced into refrigeration systems of more or less standard design. Several hundred units are in operation.

Effect of Housing Boom

The current abnormal activity in new-home construction presents an opportunity for experimentation with new ideas. We have seen the advance of radiant heating, mentioned above. Small, one-story homes, heated solely by a warm concrete floor, serving also as the foundation, have become common. Freedom from either radiators or air circulating equipment is cited in favor of this scheme.

Another home system attracting attention consists of a forced air circulation system in which heated air is circulated above each room over a false ceiling. The air merely heats the ceiling without being introduced into the room. Air introduced to a heated room through ducts shaped to the floor molding is a new scheme of some promise.

Still another new system, undergoing extensive tests at the Pierce Foundation, involves the circulation of a high-temperature heat conveying fluid from a central plant. This energizes not only the heating system of the home, but also the cooking stove, hot water heater and refrigerator.

Illustrations for this chapter were obtained through the courtesy of Henry Vogt Machine Co, Carrier Corp, American Society of Refrigerating Engineers, American Air Filter Co, York Corp, and Brown Boveri Corp.

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CHAPTER IV

CEMENT AND ROCK PRODUCTS

by R. F. FEIND AND EDWARD H. BAXA

CRUSHED STONE

Since the end of the war the pent-up demand for crushed stone for new construction of roads, dams, and other concrete structures has resulted in an increasing demand for new machinery and revision of plant design (1)

During the war very few advancements were made in the crushed stone industries Only those plants which had received orders for crushed and graded stone to be used on army airport construction and similar vital stone requirements were permitted to purchase new equipment and revise plant design to meet wartime requirements Then, too, the hurried demand for this construction material necessitated, in many cases, temporary plant changes which were not always completely suitable for the commercial production of stone after the war (2).

Certain definite trends in crushing plant design and practice are evident

Plant Design (3, 4)

In almost all of the present crushing plants, the stone from the quarry is fed to a primary crusher and then conveyed directly to the screening and re-crushing section of the plant This results in a very irregular stream of material passing through the entire plant, due to the peak loads of quarry operations With this irregular feeding, it is difficult to obtain efficient screening and proper grading of the stone. There are short periods of time when no stone is passing through the plant, at other times the screening and re-crushing section will be overloaded from the resulting operations

To improve plant operations and eliminate surge loads through the plant, a surge or storage pile is placed between the primary crusher and the remaining portion of the plant (5) A feeder is installed underneath the storage pile which feeds onto a belt conveyor, delivering the stone in an even stream to the rest of the plant; and, as the peak loads are eliminated, better grading, which is necessary to meet specifications, and greater screen capacity are obtained The present trend is to install a primary crusher, which has a large receiving opening to take the power-shovel feed, ahead of the surge pile. This crusher should have a capacity in excess of the rest of the plant beyond the surge pile since if there is a delay caused by quarry operations, the crusher will have sufficient capacity to catch up with the remaining portion of the plant and maintain an even, uninterrupted feed. The irregularities occurring in the quarry operation are due to the necessity of moving the shovel, halting shovel operations for secondary blasting, waiting for trucks, bad weather, and other quarry interruptions

In many plants where the quarry is located below the ground level, it is necessary to haul the stone up long inclines to the primary crusher, which is located above ground To eliminate this long haul up steep grades to the primary crusher, many plants have located the crusher down in the quarry below the quarry floor and elevate the stone out of the quarry by belt conveyors. The conveyors discharge the stone either to a surge pile down in the quarry, from which it will be elevated by belt conveyor to the remaining portion of the plant, or to a surge pile at ground level Other plants consider making this change (6 to 9).

A cross-section of the multi-impact pulverizing mill. Involute breaker plates break non-abrasive materials in five stages.

Screening agricultural limestone in a South Carolina plant. The double deck screen is 5 by 14 ft.

Stone Sand

When crushing stone, approximately 20 to 30 per cent is too small for coarse concrete aggregate, railroad ballast or other immediately salable products. It is sometimes very difficult to find a ready market for this fine material By processing this stone, it can be converted into salable products, such as stone sand, and in the case of limestone, into both stone sand and agricultural limestone

Stone sand is receiving considerable attention as the fine aggregate in concrete mixtures, so that many plants have installed, and others are considering the installation of new equipment for the production of this material It has become especially popular on large government projects.

Stone sand is produced by crushing and grading stone to the required specifications There are two processes, wet and dry When limestone or other non-abrasive stone is to be processed, a pulverator or hammer mill can be used to reduce the stone to the top size in the specifications The stone is fed dry to the pulverator and then fed to wet classifiers where the excess minus 100 mesh material is removed. However, where abrasive stone, such as trap rock, granite, or quartz, are being treated, wet grinding rod mills are usually considered The dry process for abrasive stone is the same as the wet, with the exception that the excess minus 100 mesh is removed in an air separator and the rod mills are operated dry.

Primary fines produced by the coarse crushing jaw or gyratory crusher are not acceptable in some cases, since these fines may contain too many flat and elongated particles. Crushing rolls also have a tendency to produce flat particles and are not used for this reason. The tendency to form flat and elongated particles depends on the physical characteristics of the stone. If the stone breaks cubical, all or a portion of it can be added to the sand produced by pulverators or rod mills In some cases the proper grading to meet specifications cannot be obtained by merely crushing the stone and removing the fines It is then necessary to screen the intermediate sizes and blend them to obtain the proper grading (10)

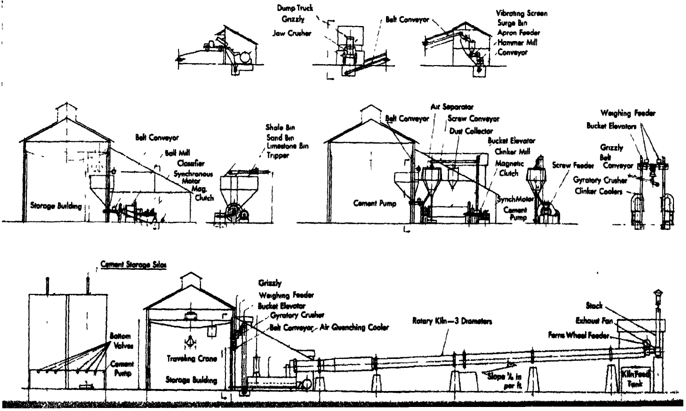
Agricultural Lime

In limestone crushing plants the fine waste material can be sold as agricultural lime (11). This material is produced by screening out the fine stone and pulverizing the oversize in hammer-type pulverators to meet the specifications

Intermediate Size Stone

The war has held up highway construction, and the post-war demand for materials or construction for new highways and reconstruction of old highways has increased greatly Due to the high cost of concrete, many of these highways are being surfaced with black top, which requires an intermediate size stone To meet this new demand, crushing plants are installing additional secondary crushers to produce a greater percentage of intermediate sizes.

UNITS FOR TYPICAL DRY PROCESS PLANT



Summary

The increased post-war demand for intermediate size stone and for crushed stone of all sizes, the desirability of maintaining an even flow of material through the plant, the demand for more cubical stone, the necessity for better size grading to meet close specifications, the increased use of stone sand and agricultural limestone, and greatly increased labor costs characterize recent trends in the crushed stone industry This has resulted in an increasing number of plant modernization programs, which should increase efficiency of operation, utilization of all products, and improve labor conditions (12 to 14)

CEMENT INDUSTRY

General Condition of the Industry

The Portland cement industry, although at present one of the healthiest in the United States, has passed through a relatively long period during which plants were forced to operate under adverse conditions

The greatest growth of the cement industry in the United States is generally considered to have occurred between 1915-1928 The normal replacement, modernization, or thorough rehabilitation of plants built during this period, or before, should have taken place between 1930 and 1940 Such normal processes were interrupted during this period by the business depression Furthermore, the demand for cement was rather low and ambitious modernization and rehabilitation programs could not be economically justified

During the years 1940-1945, when market conditions were improved and the size of the post-war demands for cement became evident, new construction and modernization of old plants could not be undertaken because of wartime limitations and shortages During this time, even the most necessary repair parts were often difficult or impossible to obtain.

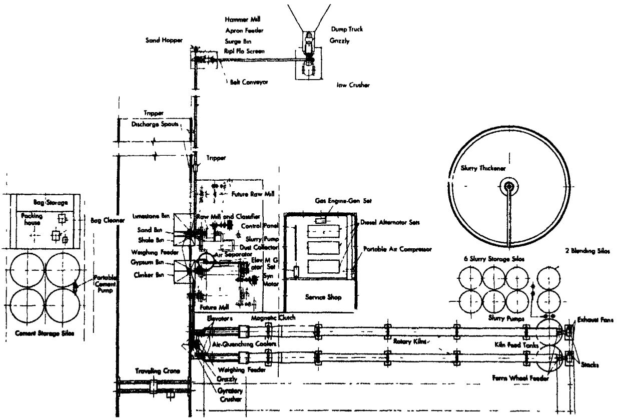
Immediately after the cessation of hostilities, the demand for Portland cement skyrocketed to new levels, which made it necessary for the plant operators to devote their entire energies, resources, and what personnel they had at their disposal toward the production of cement, at the expense of the long delayed modernization (15)

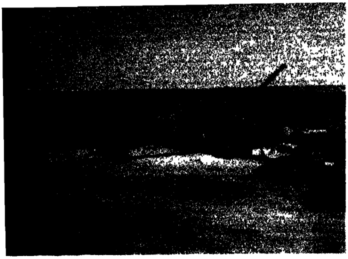
After approximately 5 years of operation under wartime conditions, most cement plants had seriously depleted, or in many cases used up entirely, their stock of repair parts Due to heavy backlogs, strikes, and steel shortages, these parts could not be quickly replaced by the manufacturers of equipment

As a result of this combination of adverse factors, many plants and considerably more equipment, which would normally have been replaced or modernized years ago, are still in operation today

Management in the cement industry realizes that the present favorable market conditions will not always exist, basing their judgment on the past history of the industry Recognizing that over a considerable share

UNITS FOR TYPICAL WET PROCESS PLANT

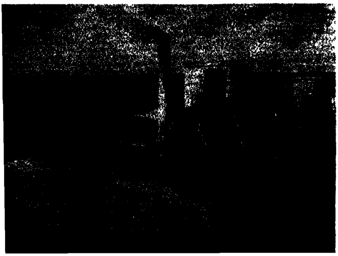




A diesel-electric engine drives jaw crusher as well as generator for electric power for vibrating screen and conveyors.

A Caterpillar diesel tractor and Kay-Brunner bulldozer load trucks with material to be crushed for road surfacing.

A modern closed-circuit grinding, wet-process cement plant of the Argentine Portland Cement Company, 200 miles north of Buenos Aires. Breerwood process provides satisfactory kiln feed from raw cement rock poor in cement-making properties.



of the last decade the cement industry had potential production capacity in excess of the demand, which led to keen competition, many plants have planned or undertaken modernization and rehabilitation programs designed to decrease their consumption of fuel, power, and man-hours (16)

The cement industry in the United States has been developed to a rather high degree, and plants have already been built and operated at strategic locations for the supply of raw materials, fuel power, and markets As a result, few very new plants are being considered completely In most instances, new construction being planned or actually underway has taken the form of rehabilitation and modernization of existing plants. They are utilizing as much of the existing structures and equipment as possible Existing structures and equipment will become a part of the modernized plant. Since new construction will be accomplished with limited manpower during a period when the demand for cement is great, the projected modernization must be worked out with a minimum of interference with the production of the existing installation Such programs can best be carried out by making careful long range plans, and carrying out the construction work in stages.

In general the overall plant design of a new plant, or a modernized existing plant, incorporates about the same features and is intended to accomplish the same results Perhaps the most outstanding trend in general plant design is toward the continuous flow of all materials This involves increased mechanical handling equipment and a minimum of storage and rehandling Such design, effectively worked out, contributes greatly toward reduction of man-hours expended per unit of output and greatly reduces the capital investment required for handling materials while in process

The continuous flow of materials shown in the accompanying diagram was largely made possible by noteworthy advances in the design of more efficient clinker coolers (17) These reduce the temperature of the rotary kiln product sufficiently so that it can pass directly to the grinding stage without the need of stock piling for final cooling

Because cement is a product on which the margin of profit per unit is small, cement plants must handle large tonnages of materials. Their transportation constitutes a sizeable portion of production costs This has dictated that plants be located both where raw materials are immediately available and the product conveniently marketed When plants were built, many of the otherwise ideal locations were not served with adequate quantities of low-cost electrical power. As a result, they were forced to produce power for their own needs. Since rotary kilns were then comparatively short and quite inefficient, many plants were installed utilizing waste heat boilers for the generation of steam.

The gradual development of longer and more efficient rotary kilns, heat recuperating devices, and the more widespread distribution of low cost electrical power, has caused many plants to abandon the use of waste heat boilers in their plans for modernization (18). Since the trends in any industry are closely linked with the developments of equipment, the various phases of cement manufacture can best be discussed under one or the other stage of the production process. In general, the objectives of the trends in the design of these departments are either to produce better cement, use man-power more efficiently, or reduce the consumption of electrical power or fuel In many cases all of these factors are involved

In order that this explanation may be made more specific and more readily understandable, the balance of this discussion will be by department, roughly corresponding to the order in which the processes are applied to materials in a plant producing Portland cement

Quarries

Many existing plants were originally designed with railroad equipment to haul materials from the quarry face to the crushing department Although this equipment was reliable and served the purpose well, large quantities of manpower were required to move continually the temporary railroad tracks in the quarry to keep them near the advancing quarry face so that the raw materials could be loaded by means of power shovels.

The development of modern motor truck and crawler crane equipment has in many cases caused existing railroad haulage equipment, with its high manpower requirement, to be replaced by motor truck haulage This is particularly true where the distance from the quarry face to the crushing plant is relatively short.

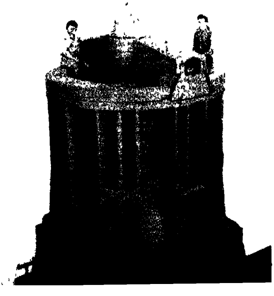
Because of the job's nature, secondary blasting is almost invariably a hand operation which requires considerable manpower In an attempt to reduce secondary blasting, and consequently the amount of manpower required to an absolute minimum, most quarries use power shovels capable of handling comparatively large pieces of stone.

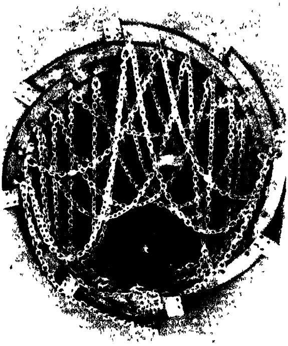
Crushing Plant

The use of larger power shovel equipment in the

Gyratory crushers provide low power and maintenance costs for high capacity primary or secondary crushing. Oil circulation is built-in.

After crushing, material is discharged through open bottom of primary gyratory crusher. Sizes range from 30-in. to 72-in. feed openings with capacities from 50 to 3500 tons per hour.





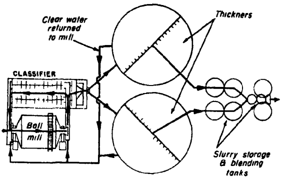
Accelerated drying of slurry in the feed end of a rotary kiln in wet process operations is achieved by a patented chain system.

Mill head is removed to show rods of high-carbon steel. Rods are designed to lower maintenance costs by reducing wear on liners and rods.

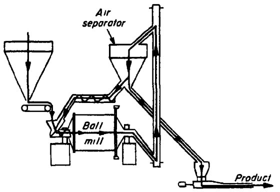
This air-quenching cooler, viewed from discharge end, transfers heat directly to combustion air and returns it to the kiln.

A quenching clinker cooler installed at Johannesburg, South Africa. Rapid heat transfer is attained by passing the cooling air through a relatively thin bed of materials. Depth of bed is automatically controlled.

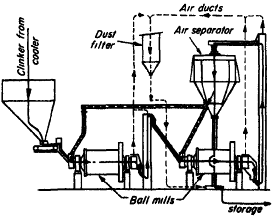
A variety of driers are available to handle all types of materials. This indirect type drier, with stainless steel shell, is installed in a chemical processing plant to handle corrosive materials.



TYPICAL SINGLE STAGE WET GRINDING CIRCUIT
BALL MILL OPERATING IN CLOSED CIRCUIT WITH WET CLASSIFIER



TYPICAL SINGLE STAGE DRY GRINDING CIRCUIT
BALL MILL OPERATING IN CLOSED CIRCUIT WITH AIR SEPARATOR



TYPICAL 2-STAGE DRY GRINDING CIRCUIT
PRIMARY MILL IN OPEN CIRCUIT, SECONDARY MILL IN CLOSED CIRCUIT WITH AIR SEPARATOR

stone quarries has led to the design and usage of primary crushing equipment having the largest possible feed openings, thus reducing the necessity for secondary blasting in the quarry

As a general rule, the tendency is to crush the raw materials to finer sizes, since the development of fine reduction crushers has made it cheaper to reduce the particle size of the raw materials within certain limits by crushing than by grinding in a ball mill

Raw Grinding Department

Perhaps the most noteworthy trend in the cement making process has been that of grinding raw materials in a relatively short ball mill, operating in closed circuit with either an air separator in dry process plants, or a wet classifier in wet process plants Such grinding circuits reduce the raw materials to a uniformly small particle size without the production of an excessive amount of extremely fine particles Closed circuit grinding is particularly advantageous when the raw material consists of a mixture of hard and soft components In the conventional open circuit mill, all of the materials would be retained in the mill until the hardest component had been reduced to the desired size In the modern closed circuit system, the materials are retained in the mill a comparatively short time, after which they are passed through the classification device where particles of an acceptable size are removed as product, and the balance, consisting of coarser particles, is returned to the mill for more grinding This method of grinding produces a more acceptable product at a power consumption of from 10 to 30 per cent less than would be used by the conventional open circuit grinding system (19)

Storage and Blending of Raw Materials

The development of more accurate and more practical feeders has led to a general trend toward obtaining more accurate proportioning of raw materials as they are fed to the raw grinding mills, thus reducing the need for an excessive capacity in blending tanks and bins.

With the increasing rigidity of cement specifications and the variety of special cements requested by consumers, there has been a tendency to favor the wet process for the manufacture of cement, mainly because it is more feasible to blend raw materials for special cements in the form of a liquid slurry than it would be to blend these materials in a dry, finely ground state (20, 21, 22).

Burning Department

Because the fuel consumed for the production of cement is one of the largest items in the cost of cement production, considerable attention has been given to the development of rotary kilns and auxiliary heat recuperating equipment. Perhaps the most noticeable trend in the cement industry is toward the use of longer rotary kilns and the most effective heat recuperating equipment obtainable (23).

When most of the existing cement plants were built, rotary kilns used had an average length of between 150 and 200 ft. The rotary kilns used in modern plants have an average length well over 300 ft with a maximum length of around 500 ft

These longer rotary kilns employ such heat recuperating devices as chain systems (on wet process kilns) and air quenching coolers These coolers recover as much as 75 per cent of the sensible heat in the clinker as it is discharged from the kiln and return it to the kiln in the form of preheated air for combustion (24). They also render the clinker easier to grind (25), and cool it to a temperature where it can be passed directly to the clinker grinding department This eliminates, to a large extent, the necessity of stock piling for final cooling

Modern rotary kilns employ many automatic controls and instruments to control and record temperatures pressures, and other performance characteristics This permits operators and management to check carefully on the performance of various units The recording of such performance data improves the utilization of fuel (26), materials, and manpower with a degree of efficiency which was previously impossible

Clinker Grinding

Heretofore the clinker produced in rotary kilns, after being cooled in inefficient coolers and stock piles, was blended with a certain proportion of gypsum and fed into long compartment mills, so that all compartments should be doing their relative proportion of the work (27) However, some compartments would run either overloaded or underloaded at almost all times, thus reducing the overall efficiency of the grinding mill Some attempts were made to overcome this by using integral screens, various kinds of division heads between compartments, and other devices which gave some desirable results but which led to considerable complication of the entire unit The latest trend in equipment is to do clinker grinding in two stages The preliminary mill usually operates in open circuit, the product going to the secondary mill

The secondary mill operates in closed circuit with an air separator, the oversize from which can be returned in any proportion to the feed end of either of the two mills With such an arrangement, it is possible to balance the work between the two mills, adding greatly to the efficiency of the entire circuit

The difficulty in obtaining spare parts experienced by most operators in recent years has no doubt been the basis for the renewed tendency to use duplicate mills in the raw and finish grinding sections, even though the circuits in which they are used may be somewhat different By such careful planning, it is possible to operate several mills with only one stock of spare parts.

Packing Department

The packing departments of most cement plants have not changed in principle for many years. However, most modern cement plants find it necessary to maintain a rather large number of cement storage silos with a very flexible handling system for either bulk loading or packing into bags. There has been, and no doubt will continue to be, a decided tendency for large consumers of cement to sample, test, and purchase an entire silo full of cement to be held in storage for them at the cement plant until it is delivered. This practice makes it necessary for the cement plants catering to large consumers to have rather large storage facilities.

New Products of the Industry

Large amounts of research work are contiually being done by the cement industry to develop cements to meet specialized job conditions and to obtain certain characteristics. It can be said that cements have been developed to meet almost every major construction problem. Perhaps the most notable of these recent advances has been the development of air entraining cement, which has been found superior to any previous product in resisting repeated thawing and freezing, and resisting the effects of chemicals now so commonly used on roads to remove ice and snow (28 to 31).

Air entraining cement also has advantages in that the concrete resulting from its use is more fluid and can be more readily worked into forms

Summary

In general, the attention of cement plant operators and management has, for the past few years, been directed toward production. Plans for rehabilitation have been made but the actual execution of these plans has not reached its peak.

A concrete pumping machine, showing section pipes, two concrete mixers, and wooden channels above. Used in the construction of a Mexico City office building.

Since many of the major developments requiring a pronounced departure from existing practice originate with the operators (32), additional new developments in the industry can be expected as soon as the rehabilitation program gets underway (33).

Illustrations for this chapter were obtained through the courtesy of Allis-Chalmers Manufacturing Co, Pioneer Engineering Works, Inc. Caterpillar, Lone Star Cement Corp, Nordberg Manufacturing Co, and Chain Belt Co.

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CHAPTER V

CHEMICAL INDUSTRY

by F. J. VAN ANTWERPEN AND S. L. TYLER

Synthetic Fuels

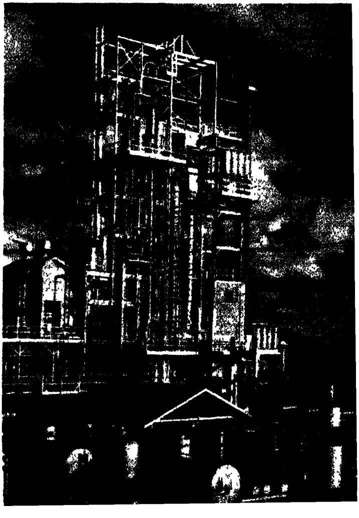
The largest single technical advance publicized in the United States during 1947, was toward the perfection of a process for making liquid fuels from natural gas or coal. The process for making such fuels is basically the Fischer-Tropsch synthesis of which there are many variations. Various trade names applied to this reaction are Kogasin, Synthol, Synthine, O. X. O., and Hydrocol (1). Two plants are now being built in the United States for the production of liquid fuels from natural gas (2). They are the Carthage-Hydrocol plant at Brownsville, Texas, and the plant being built for the Stanolind Oil and Gas Company at Hugoton, Kansas.

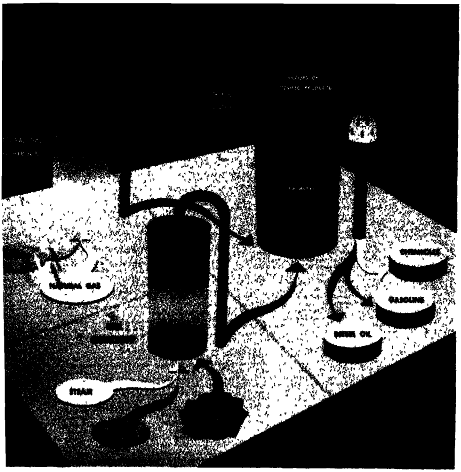
The synthesis as developed in the United States differs in many ways from the old Fischer-Tropsch process of the Germans. The basis for the German development is the gasification of coke from lignite materials, using steam and air or oxygen to make a mixture of carbon monoxide and hydrogen. This gas was reacted in massive heat exchangers over a cobalt-thoria catalyst. The limitation of the German process was that of removing the heat generated. The American process begins with natural gas to make a "synthesis gas" of carbon monoxide and hydrogen. This reaction is carried out in the presence of high purity oxygen and development of a cheap process for producing oxygen is another important phase of chemical development which evolved through the year, and this will be covered in this article.

For conversion of a "synthesis gas" to liquid products, the mixture is reacted in the presence of a fluidized iron catalyst. The fluidization of catalysts is a war time development in the United States, and by reacting the synthesis gas in the presence of a turbulent, fluid, solid gas catalyst, the exothermic conditions are controlled very easily, either by heat exchangers in the reaction bed or by removal of the hot catalyst by blowing it out of the reactor at a faster rate (3,4). The various processes differ mainly in the manner in which the synthetic gas is treated to make the hydrocarbon products. The Kogasin synthesis utilizes a synthesis gas in the ratio of one carbon monoxide to two of hydrogen, and iron, cobalt, and nickel catalysts at atmospheric pressures. The Synthol synthesis varies the radio of carbon monoxide to hydrogen from 1:2, to 1:1, and the catalyst used is an alkali treated iron. The pressure is high—about 150 atmospheres. The difference between the two is that the Kogasin process produces carbon dioxide. In the O. X. O. process, olefins are charged along with the synthetic gas to produce aldehydes.

The producing units now being planned for the United States are estimated to have a capacity of 7000 barrels a day. It is expected that they will produce 5800 barrels of gasoline, and 1200 barrels of diesel oil. The cost of producing synthetic fuel in the United States, where natural gas costs 5¢ (U. S. cy) per 1000 cu. ft. is said, by the designers of the Hydrocol process to be competitive with the liquid fuels now being made from petroleum. In addition to the gasoline and diesel oils produced, there will be a tremendous quantity of chemicals as by-products and it is expected because of this the processes will become a principal source of basic organic chemicals, particularly those used in the cellulose plastics, and acetate rayon industries. It has been estimated (2) that 10 such plants will produce chemicals equivalent to 26 per cent of the acetaldehyde used

Large pilot plant converts natural gas to gasoline by modified Fischer-Tropsch process.





Synthetic gasoline is made from natural gas or coal in a two-stage process. First stage produces a mixture of carbon monoxide and hydrogen. The second stage synthesizes the hydrocarbons from these gases which form the final products.

When natural gas is used as the raw material, it is burned in a generator with a limited supply of oxygen to produce carbon monoxide and hydrogen. When coal or coke is used it is brought to high temperature by an oxygen blast in the presence of steam. The oxygen and steam combine with the carbon in coal or coke to produce the desired mixture of gases.

In the second stage of the process, the mixture flows into chamber containing the catalyst. Here carbon monoxide and hydrogen react to form the hydrocarbon gases and vapors from which the finished products—synthetic gasoline, Diesel oil and chemicals—are condensed and separated out.

in the United States at present, 33 per cent of the acetone, 77 per cent of the ethanol, 35 per cent of the normal butyl alcohol, 71 per cent of the normal amyl alcohol, and 87 per cent of the acetic acid. The estimated production of organic chemicals from the Carthage-Hydrocol plant is shown below (2). The Hydrocol technique is similar to the Synthine process described above.

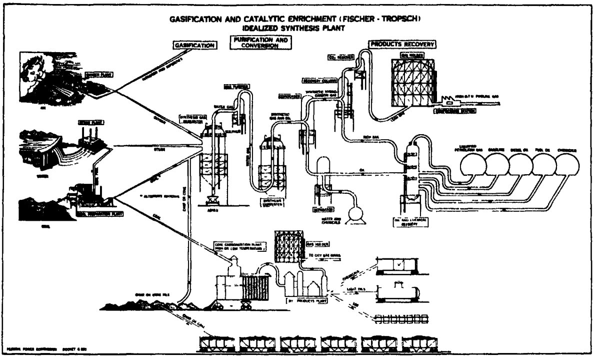
CARTHAGE-HYDROCOLS CHEMICAL PRODUCTION

Annual Production
(in 1,000 lbs)

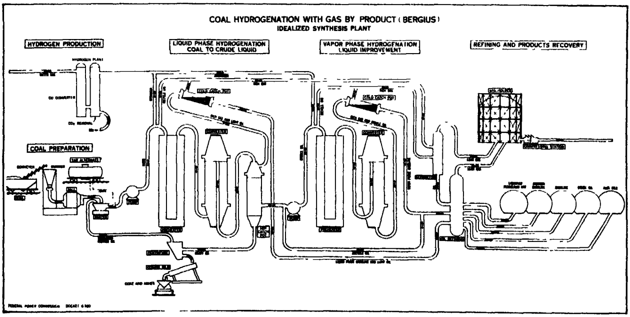
Chemical	*Production*
Methyl alcohol	730
Ethyl alcohol	63,680
n-Propyl alcohol	14,400
n-Butyl alcohol	4,370
n-Amyl alcohol	1,060
Acetaldehyde	9,100
Propionaldehyde	1,930
n-Butyraldehyde	2,750
Acetic acid	24,700
Propionic acid	8,700
n-Butyric acid	4,200
Acetone	11,200
Methyl ethyl ketone	4,780
Methyl n-butyl ketone	250
Methyl n-propyl ketone	600
Total	152,450

Some concern is being shown for the supply of natural gas in the United States, and whether there will be enough available for the synthesis plants when they are ready for operation However, testimony given before the Senate (5) indicates that sufficient quantities of gas are available to supply raw materials for the synthesis of 300,000 to 500,000 barrels a day of liquid fuels. The fact is that large quantities of natural gas are available far from centers which would use the material as fuel, and such fields are primary locations for the construction of synthesis plants The production of chemicals from this source is almost a certainty, and recently one large chemical company announced that it entered into an arrangement to purchase all the water soluble organic chemicals from the Brownsville and Hugoton plants

At a meeting of the American Institute of Chemical Engineers at Detroit, W. C. Schroeder, Chief of the Office of Synthetic Liquid Fuels, Bureau of Mines, stated that the current high demand for liquid fuels makes the synthetic production of fuels feasible now. There is a petroleum shortage in the United States, and he states as proof the gasoline rationing in the mid-West during the summer of 1947. The reasons for the shortage of petroleum at present, aside from securing steel necessary for building new facilities, is the low rate of discovery of petroleum reserves. Exploration after 1938 has provided about only half of the oil we have been using. This has not been due to a low rate of exploration, but during 1946 and the early part of 1947, 3 or 4 times as much work has gone into exploration as before the war. The lack of petroleum is due to increasing difficulty in finding it. The second important


GASIFICATION AND CATALYTIC ENRICHMENT (FISCHER - TROPSCH)
IDEALIZED SYNTHESIS PLANT
GASIFICATION
PURIFICATION AND CONVERSION
PRODUCTS RECOVERY

Although plant investment is about triple, synthetic gasoline will cost about the same as that from crude oil.


COAL HYDROGENATION WITH GAS BY PRODUCT (BERGIUS)
IDEALIZED SYNTHESIS PLANT
HYDROGEN PRODUCTION
LIQUID PHASE HYDROGENATION COAL TO CRUDE LIQUID
VAPOR PHASE HYDROGENATION LIQUID IMPROVEMENT
REFINING AND PRODUCTS RECOVERY
COAL PREPARATION

Utilization of vast coal resources is possible through the high pressure hydrogenation process developed by the U. S. Bureau of Mines; this process (Bergius) originated in Germany.

factor is the sharp rise in the demand for oil. At the present time 90 per cent of the locomotives on order have oil-burning Diesel motors. The demand is at the highest rate in history. The automobiles now in use are consuming more oil per car than before the war, farms and farm machinery are demanding more and more oil, and in addition we have a growing aviation industry needing larger quantities of high-octane gasoline.

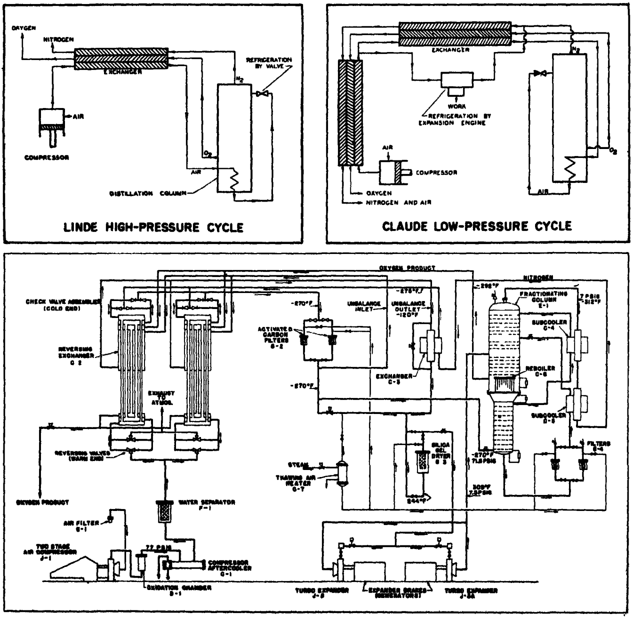
All of this has resulted in the need for petroleum of 4 million barrels a day before the war, to 5 million barrels a day during the war, and to 5.5 a day at the present time. It is predicted that before 1951, the demand will reach 6 million barrels. It is not possible to supply such demand from our present reserves, and there is no promise that the reserves can be increased sufficiently by further exploration. Hence production of synthetic liquid fuel is seen and planned as a logical source of supply.

Natural gas was not the only source of hydrocarbons for this synthesis. In March of last year the Pittsburgh Consolidated Coal Company and the Standard Oil Development Company, which is the central technical organization of the Standard Oil Company of New Jersey, announced that they were building a pilot plant to study the complete gasification of coal. They will spend about $500,000 on the experimental work, which will stress the application of the fluid catalyst process to the gasification of coal. The objective is to obtain "synthesis gas" for a Fischer-Tropsch plant. The pilot plant that is being constructed is planned to consume about 50 tons of coal a day, and will produce about 2.5 million cubic feet of gas suitable for synthesis into liquid fuels, and also into a gas fuel as a heat source for manufacturing purposes Company officials visualize construction of huge gasification plants at local mine mouths, and the high volatile coal of the Pittsburgh region is said to be quite satisfactory for this purpose As for cost, while the production of gasoline from natural gas is competitive at present with petroleum produced gasoline which brings at the service station about 22¢ a gallon, it was felt that gasoline from coal could not be sold for less than 30¢ a gallon.

Preliminary work indicates that about 100 gal of synthetic gasoline and diesel fuel will be obtained from a ton of coal (6). Other uses have been visualized for the Fischer-Tropsch process (1, 7). In addition to the use of gas from coal, it has been suggested that fuel oil be used to make synthesis gas which would in turn be converted to gasoline. It was also suggested that the Fischer-Tropsch plant burn the heavy, coky materials of petroleum refineries which are not being used to best advantage at present.

Oxygen Production

One of the important adjuncts is the production of large quantities of relatively high purity oxygen (1, 8 to 15) The use of oxygen produced by the Linde-Frankl process is well known High purity, better than 99 5 per cent oxygen, is necessary for the present industrial uses of liquid oxygen and the Linde-Frankl process turns out such a product However, during the war, extensive research was carried out in the United States on the production of oxygen for use in high altitude aircraft The product did not have to be of extreme purity, and from the war research have come many new ideas



Top—two elementary cycles for liquefying air; Bottom—Flow diagram of the commercial process for making medium purity oxygen.

and a great impetus for the production, on an industrial scale, of oxygen of about 90 per cent purity During the year the Linde Air Products Company announced that they had in operation a modified Linde cycle which, having a steady gas demand, could produce gaseous 90 per cent oxygen at 3 lb pressure for less than $6.00 a ton The pilot plant they have in operation has a capacity of 200 tons of oxygen a day (13)

The uses envisaged for low cost oxygen have been listed (1) They are.

(a) For the production of gas from coal by continuous complete gasification for use as city gas of current or increased thermal content

(b) For the production of gas with a composition suitable for synthesizing hydrocarbons, oxygenated products and ammonia from coal and natural gas

(c) For the oxidation of ammonia and sulphur dioxide and for the partial oxidation of organic compounds to derivatives.

(d) For the roasting and burning of sulphide ore, pyrites and other sulphur-containing compounds

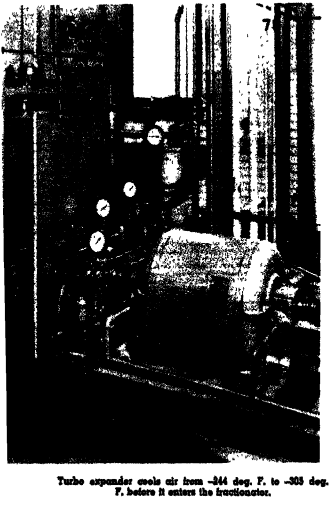
(e) For the smelting of iron ores and the refining of iron in Bessemer converters and open hearths

(f) For the combustion of fuels where unusually high temperatures are advantageous, such as calcining and perhaps even for the direct combination of nitrogen and oxygen

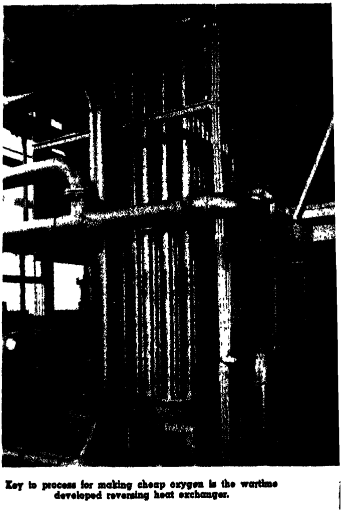
There is a possibility that cheap oxygen may revive the Deacon process, and that hydrogen peroxide may be found more economical to make from hydrogen and oxygen than by other methods

There are several cycles under consideration for the production of oxygen (8, 9, 13 to 15) The processes divide themselves into low pressure and high pressure cycles, both offering certain advantages One major problem to be overcome in any oxygen process is the purification of the compressed air used as a source of the oxygen The air contains entrained solid and liquid particles of water, carbon dioxide, and hydrocarbons which will condense in the low temperature heat exchangers, and clog and make inoperable these pieces of equipment This is a major stumbling block in air separation work and extensive precautions are taken to overcome this difficulty, including chemical purification of air, bleeding-off of accumulated impurities, and reversible air flows It is now thought possible to purify low pressure air without the use of any clean-up chemicals, and the success of this work has made it possible to take advantage of high speed and rotary

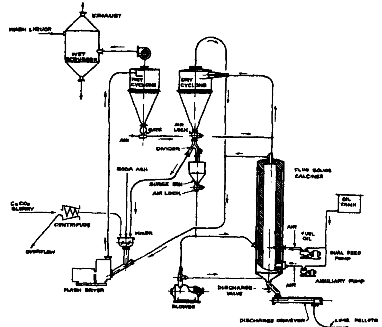
(Continued on page 114)



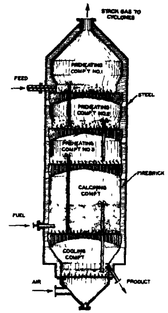
Turbo expander cools air from −244 deg. F. to −303 deg. F. before it enters the fractionator.



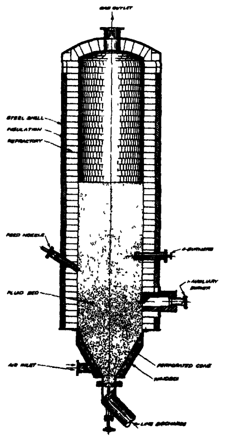
Key to process for making cheap oxygen is the wartime developed reversing heat exchanger.



FLOW DIAGRAM - FLUOSOLIDS LIME SLUDGE CALCINATION



FLUO SOLIDS LIME KILN



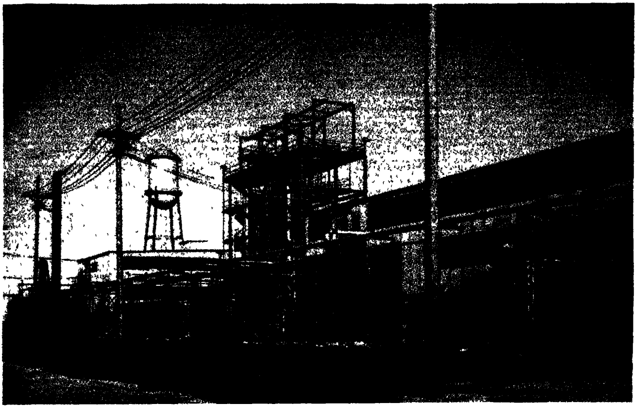
THE DORRCO FLUOSOLIDS CALCINER

FLUIDIZATION OF SOLIDS is an important new unit operation. Its most important application, the catalytic cracking of petroleum, was developed by the Standard Oil Development Co early in the war and soon became the most important of the cracking processes (see chapter on the "Petroleum Industry"). Non-catalytic fluidization has been applied successfully to limestone calcination by a process known as Fluo Solids developed by the Dorr Co.

Fluidization may be defined as a unit operation wherein a mass of finely divided solids is maintained in a turbulent state resembling a boiling liquid by an upward moving gas stream. Similar to most unit operations, there are a number of limitations that must be considered. However, fluidization appears to be particularly advantageous in a number of applications. Included in these are calcination of limestone, dolomite, magnesite, metal hydrides; pigments and other similar materials; partial calcination such as is used in reducing magnesium carbonate without more than slightly altering the calcium carbonate; reduction of metallic oxides; oxidation with air at high temperature; roasting of arseno-pyrites and sulphides of zinc, copper and iron; chlorination; conversion of copper oxide to copper sulphate; heat transfer operations wherein sensible heat is changed from solid to gas phase or vice versa. A number of these applications have been investigated on a pilot plant scale.

The flow diagram above illustrates a Fluo Solids unit for lime sludge calcination in such industries as sulphate pulp, water softening and beet sugar processing. The lime kiln and calciner illustrated are examples of a variety of different equipment designs.

SILICONES OFFER NEW FIELD FOR PRODUCT DEVELOPMENT

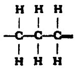


Important new products not available before the war are silicones; in this plant are produced a wide variety of silicones in the form of fluids, resins, varnishes, greases and elastomers.

Silicone Chemistry, In Brief

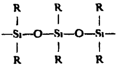
The first step in the manufacture of silicones is the conversion of sand (silicon dioxide) to silicon tetrachloride ($SiCl_4$) through the use of chlorine obtained by the electrolysis of brine From coal and petroleum are derived several hydrocarbons, such as benzene, methane, and ethane These converted to chlorohydrocarbons by reaction with chlorine One or more of these chlorinated hydrocarbons are reacted with magnesium to form a Grignard reagent which then is combined with the silicon tetrachloride The product is magnesium chloride (akin to the original brine) and a mixture of organo-silicon chlorides These organo-silicon chlorides have some hydrocarbon bound directly to the silicon atom in place of one or more of the chlorine atoms originally attached to silicon to form silicon tetrachloride The hydrocarbon unit may be any one of many possible ones, depending on the nature of the product sought It may be CH_3 or C_2H_5 for example. In any case it is thought of as a unit and is termed the hydrocarbon radical, or simply *R* When treated with water, the organo-silicon chlorides react to form hydrochloric acid and organo-silicon oxide condensation products known to chemists as polysiloxanes These large molecules built upon a silicon-oxygen linkage are the units used in the molecular architecture of the silicones.

These large silicone molecular structures have approximate analogues among the hydrocarbons. But there is an important and essential difference In the hydrocarbons each carbon atom is linked to an adjoining carbon atom, thus:



$$\begin{array}{ccccccc} & H & & H & & H & \\ & | & & | & & | & \\ - & C & - & C & - & C & - \\ & | & & | & & | & \\ & H & & H & & H & \end{array}$$

In the silicones, however, each silicon atom is linked to an adjoining oxygen atom in this fashion:

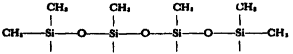


$$\begin{array}{ccccccccc} & R & & & R & & & R & \\ & | & & & | & & & | & \\ - & Si & - & O & - Si - & O & - & Si & - \\ & | & & & | & & & | & \\ & R & & & R & & & R & \end{array}$$

It is this silicon-to oxygen bond that gives the silicones some of their most valuable properties

The hydrocarbon radical is the only organic component and is bonded directly to the silicon atoms The resulting silicone is, then, clearly neither organic nor wholly inorganic It lies midway between the two conventional fields of chemistry and may be termed a semi-inorganic compound. There are many possible hydrocarbon radicals, but CH_3 (methyl), C_2H_5 (ethyl), and C_6H_5 (phenyl) are the more common ones Choice of a given hydrocarbon unit from among many is one of the several variables available to the silicone molecular engineer

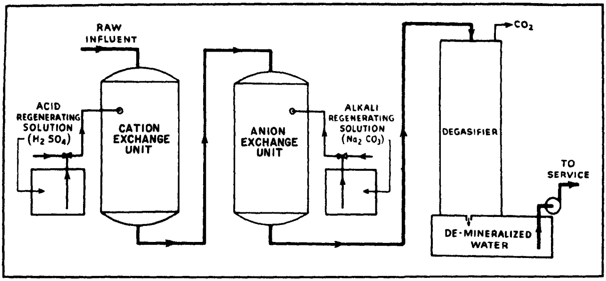
Another variable in the design of a silicone is the length of the chain This chain may be only a few silicon-oxygen-silicon links long, or thousands of these organo-silicon oxide units may be linked together Eventually, each molecule must be terminated by a blocking unit, which can be an *R* unit in place of an oxygen atom. The chemist can allow the molecule to grow to almost any desired length, and stop further growth by adding a blocking unit, thus:



$$\begin{array}{ccccccccccc} & & CH_3 & & CH_3 & & CH_3 & & CH_3 & & \\ & & | & & | & & | & & | & & \\ CH_3 & - & Si & - O - & Si & - O - & Si & - O - & Si & - & CH_3 \\ & & | & & | & & | & & | & & \\ & & CH_3 & & CH_3 & & CH_3 & & CH_3 & & \end{array}$$

Thus we have a straight-chain molecule However, one chain can be linked to the adjoining molecule by cross links to form a three-dimensional structure This is still another variable useful to the architect of silicone molecules.

(Westinghouse Engineer)



Ion exchange system for demineralizing water; this basic system is used in all deionizing applications.

Instruments responsible for complete automatic control in the deionization of pineapple juice.

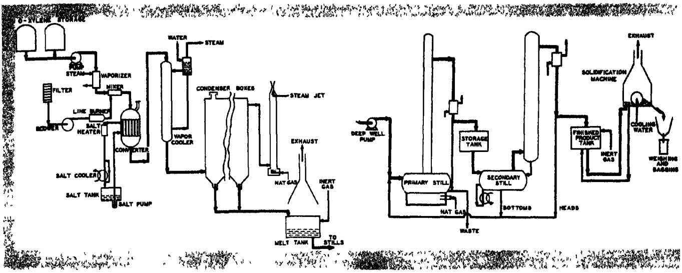
Installation of ion exchange cells used in recovering sugar sirup from waste pineapple juice.

ION EXCHANGE is not new but it has become important in the chemical and allied industries. Most significant is its application to the purification of sugar juices in the sugar and food fields. Water treating is still the largest user of ion exchange wherein the chemical equivalent of distilled water can be produced at a fraction of the cost of distilled water.

Ion exchange has been defined as the reversible interchange of ions between a solid and liquid in which the structure of the solid does not change. There are two types of ion exchange, namely, cation exchange which removes positive ions from solution and anion exchange which removes negative ions from solution. Thus it is possible to remove all ionizable substances from solution whether they be acidic or basic in character. Reversibility of the reaction makes possible regeneration of the ion exchange materials.

Most of the newer applications of ion exchange stem from the development, 10-15 years ago, of organic ion exchange materials. Synthetic resins and materials such as sulphonated coal made possible the exchange of hydrogen ions, as well as the metallic ions exchanged by the zeolites, and led to the development of acid adsorbent resins. Complete deionization thus became a commercial reality.

A wide variety of uses for ion exchange have been investigated in the laboratory and pilot plant and have resulted in a good many commercial installations. In addition to water treatment and sugar juice purification these applications include the following: removal of formic acid from formaldehyde; recovering copper from cuprammonium textile wastes; streptomycin purification, artificial ageing of whiskey; recovery of alkaloids; recovery of pectin from grapefruit peel; removal of sulphuric acid from sulphonated oils; reduction of calcium content of milk for infant feeding; purifying sorbitol; and removal of sulphuric acid from ethylene glycol.

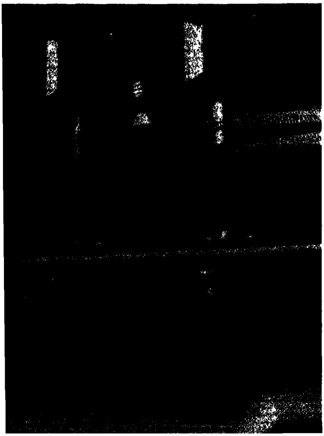


Flow diagram showing the production of phthalic anhydride from ortho-xylene.

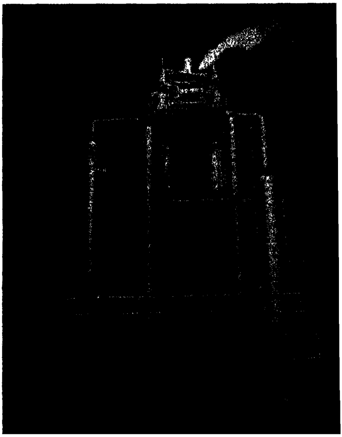
An example of the increasing importance of petroleum as a chemical raw material is the catalytic oxidation of ortho-xylene, a petroleum product, to phthalic anhydride. Prior to the commercial development of this process by Oronite Chemical Co at Richmond, Calif., phthalic anhydride had always been manufactured from naphthalene, a derivative coal tar produced in the by-product coke oven industry.

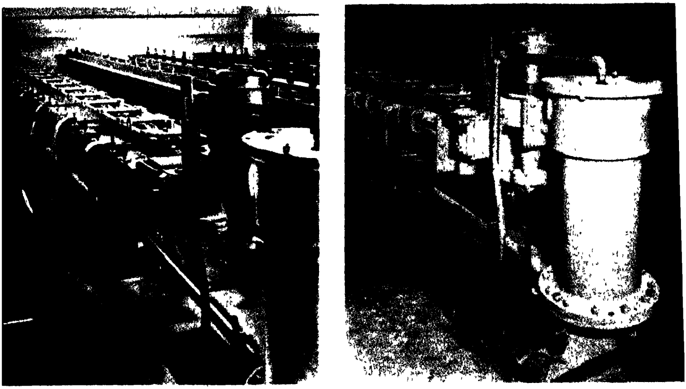
Raw material is supplied by the hydroformer unit in the adjacent refinery of Standard of California. The xylene feed is pumped from storage tanks into the converters after being vaporized and mixed with pre-heated air. In the converters, the air-xylene vapors pass through bundles of tubes filled with a vanadium oxide base catalyst where oxidation to phthalic anhydride takes place at a relatively high temperature. Reacted vapor mass leaves the converters and passes through coolers after which crystals of phthalic anhydride are formed. These crude crystals are melted and pumped to the primary still. The secondary still is equipped with a fractionating column where final purification of the product takes place. The purified distilled product is chilled and formed into flakes which are automatically weighed into bags for storage and shipping.

Intake filters and centrifugal compressors supply air to the converter for oxidizing ortho-xylene.



Distillation unit purifies the crude phthalic anhydride; primary still is on the left.



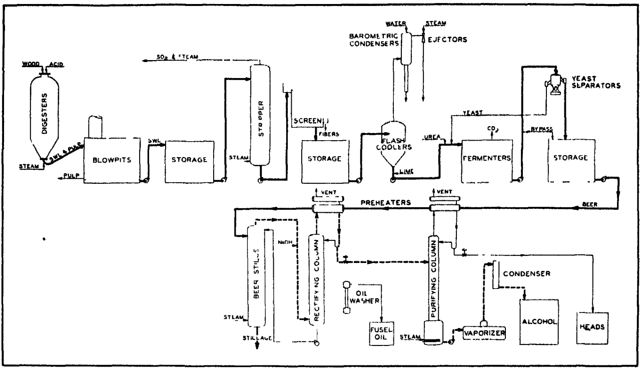


A new mercury cell for making chlorine and caustic soda by the Mathieson Alkali Works, Niagara Falls, N. Y. At the left is the new mercury cell developed with the Aluminum Co of America and installed at Arvida, Quebec. At the right is shown a tower type amalgam decomposer with the mercury pump and part of the electrolyser. Some advantages of the Mathieson cell over similar German cells are listed as follows: Calcium sulphate can be tolerated, making it possible to avoid use of barium carbonate; requires less than 2/3 the floor space; and it has lower energy consumption. This cell has been licensed and made available to several companies.

centrifugal air compressors New types of heat exchangers have been developed for low and high pressure cycles The heat exchangers for low pressure plants serve a dual purpose acting as air purifiers as well as heat exchangers (9) For aircraft use, a low-pressure, compact, cycle was developed capable of producing 150 cu ft of 99 per cent oxygen an hour The cycle featured a heat exchanger which transferred heat from incoming compressed air to exit nitrogen and oxygen, and also removed water, carbon dioxide, and hydrocarbons It also introduced the reciprocating expander (12) It is in the concept of the heat exchangers that most of the new processes differ, since they represent a break with the classical Linde-Frankl cycle In the Linde-Frankl cycle, water vapor and carbon dioxide are removed by freezing out in regenerators which contain huge masses of heat-exchange surfaces. One cu ft of packing produces a heat transfer surface of about 2,000 sq. ft. The air, being purified, flows through the heat transfer surface at compressor discharge pressure, giving up heat and freezing out impurities. The oxygen and nitrogen gas flows through the generator at a pressure only slightly above atmospheric, taking up heat and the impurities. The cycle requires four regenerators, two operating alternately on air and nitrogen, and two operating alternately on air and oxygen. The oxygen coming from the Linde-Frankl cycle contains a small amount of impurities. In the reversing exchanger processes (10), some of the disadvantages or impurities are expected to be eliminated In operation the air from the compressors is cooled in counter-flow in one of two heat exchanger tubes against waste nitrogen The oxygen travels uninterruptedly through another passage in the exchanger As the air is cooled it deposits its impurities, and 'to prevent blocking, the exchanger is reversed periodically and the nitrogen evaporates the impurities that have been deposited by the air The air passes to the fractionating columns where it is separated into oxygen and nitrogen Up to the present, most of the plants for production of low-cost, low-purity oxygen are in the planning stage, but pilot plant work indicates that commercial size units will be successful in producing cheap, gaseous oxygen for tonnage consumption by many industries. Several pilot plants were reported in actual operation and performing according to expectations. Orders for such plants are known to have been accepted and in general the development proved to be one of the important new industries of the year

Fluorine

One of the important war developments concerned the investigation of fluorine and its compounds (16). The work on the Atom Bomb led to the production of uranium hexafluorides, and though all this work is not yet reported, much of the supplementary and supporting data is now being published. It is expected that the basic research into fluorine and its compounds will



Flow diagram for producing alcohol from waste sulphite liquor. Commercial fermentation of the sugars in waste liquor, from the sulphite pulping process, is a real advance in waste utilization. The Puget Sound Pulp & Timber Co, Bellingham, Wash., has been operating this plant since March 1945. The process is comprised of the following steps: (a) Separation of sulphite waste liquor and collection in storage. (b) Conditioning sulphite waste liquor for fermentation. (c) Addition of yeast and continuous fermentation. (d) Separation of yeast from fermented liquor for re-use. (e) Separation, concentration and purification of alcohol by distillation.

create new industries that will increase in importance as the years progress. The production of fluorine is by electrolysis, with nickel or carbon anodes, of a fused potassium bifluoride. Fluorine is shipped in small pressure cylinders at a cost of about $20.00 a lb. (17)

At present, the important fluorine compounds, aside from the uranium hexafluorides used in the production of the Atom Bomb, are the Freons used for refrigeration, air conditioning, and as the carrying agents in aerosol bombs used for insect control, and hydrogen fluoride, used by gasoline producers to make high octane gasoline by alkylation. Many other inorganic fluorine compounds have been known and used, and a new plastic, teflon, made by the polymerization of tetrafluoroethylene was recently announced.

A complete issue of one magazine (16) was devoted to fluorine. The research is expected to lead to new lubricants which will withstand extremely high temperatures. Another use envisaged is the manufacture of sulphur hexafluoride, a promising dielectric gas for high voltage use.

The chief supply of gas is fluorospar and it is manufactured through the electrolysis of anhydrous hydrogen fluoride; the electrolyte is a solution of potassium fluoride in anhydrous hydrogen fluoride. The shipment of fluorine is difficult, since it must be sent as a compressed gas. Its critical temperature is minus 129 deg. C., and pressure has been limited by the I.C.C. to 400 lbs. per sq. in.

Diffusion Process

During the year engineers evaluated critically the use of diffusion operations for the purification of chemicals (19, 20), and for the separation of materials which are difficult to resolve by the ordinary methods of distillation or centrifugation. The reason behind the critical examination of the gaseous diffusion process was its successful use in the atomic work at Oak Ridge, Tennessee, for the isolation of uranium 235 from a mixture of it and uranium 238. Because of the efficiencies and equipment costs involved in the separation, it was concluded that the method apparently had only one special application — the concentration and separation of uranium isotopes. It was asserted that only in rare cases would the operation be economical in the face of other systems available.

Activated Silica

The use of activated silica for large scale coagulation processes, the treatment of sewage, oil waste and paper mill white water (18) came into greater prominence during the year. The material is used when rapid and thorough coagulation is needed for clarification and purification processes.

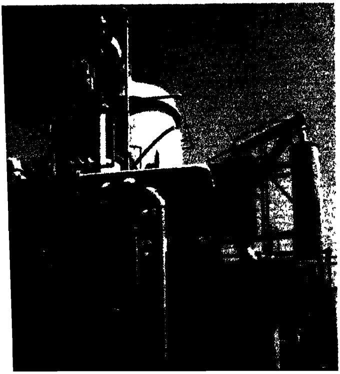
Underground Gasification of Coal

One of the by-products of industry interest in the Fischer-Tropsch process, and the various methods of producing a "synthesis gas," was the underground gasification of coal. Work has been done over a number of

First step in production of streptomycin is fermentation in closed tanks under aseptic conditions.

Penicillin fermenters, each with a capacity of 15,000 gal, are carefully controlled during operation.

Acetone evaporation equipment used in separating penicillin from the acetone extraction liquor.



years on this problem, but various factors have prevented success (21-23). This year a large-scale gasification experiment was tried and at the Gorgas Mine, the Alabama Power Company, in co-opration with the Bureau of Mines (24, 25), ignited an isolated block of coal 100 ft wide, 300 ft long, and 36 in. thick, under an overburden of 30 ft Air, and air enriched with oxygen, was used for combustion which in gasification work of this sort is partial and not complete No difficulty was experienced in maintaining combustion and it was demonstrated that a "synthesis gas" could be made continuously A gas was generated at 1 5 lb per sq in (the overburden depth determines this pressure) having a B T U content as high as 222 B T.U. a cu ft After about a month of operation the experiment was stopped, and the underground section was examined

Cheaper Cyanides

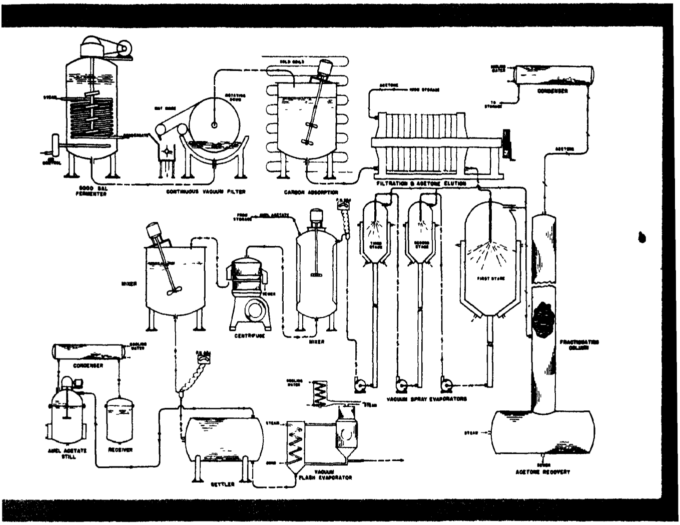
Industry also looked at a way of making cyanides by a three-step process The Germans were reported to have been making 460 tons of hydrogen cyanide a month (26) with the system and it was being suggested for consideration of American firms. The method consists in reacting methanol with carbon dioxide to form methyl formate, the conversion of the formate to the formamide by reaction with ammonia, and finally dehydration of the formamide to hydrogen cyanide The process is thought to provide a cheaper source of cyanide and cyanide compounds for the plastic, rubber and mining fields

Nylon From Furfural

During the year the du Pont Company announced (27) an intriguing process for making nylon polymer from furfural, a product obtained from agricultural by-products, such as oat hulls, corn cobs, etc, in fact from any vegetation containing pentosans (28) Both compounds (adipic acid and hexamethylenediamine) used to form the nylon polymer may be made from furfural, but the synthesis announced by the company envisaged the production of adiponitrile, which would be used to make hexamethylenediamine. The company is building a plant at Niagara Falls to carry out the procedure Adipic acid, the other constituent of nylon, will continue to be made from benzene, since its manufacture from furfural offers no economic advantage over the present synthesis

Blast Furnace Operations

Increasing production of installed capacity in the face of rising material and labor costs occupied the attention of the engineers. Steel production was aided by the development of a new process by a firm of chemical consultants, A. D. Little, Inc., in conjunction with the Republic Steel Corporation. It was found that by slight modification, blast furnaces can be throttled to operate under a pressure substantially above normal, with a resulting 20 per cent increase in its output and a 12 per cent reduction in coke consumption for each ton of iron produced By blowing air at 40 lbs. a sq. in. into the bottom of a furnace, which had been modified by installing a one-piece hopper to insure a tight seat for the bell, equalizing valves and a throttling valve to regulate top pressure, the increased production is obtained. New blowers are also required on the furnace,



Penicillin flow diagram: First of the important antibiotics, penicillin is made in a number of plants throughout the country. Twenty-one manufacturers pooled research efforts under OSRD to develop this industry.

since the volume and pressures of air are increased over normal operation (29).

Groundwood Bleaching

Reported also (30) was the first successful bleaching of a mixture of groundwood and sulphite pulp by a continuous sodium peroxide process The bleaching solution, which is a mixture of sodium peroxide, sodium silicate, sulphuric acid, and magnesium sulfate, is added to the mixed pulp for a period of time necessary to complete the bleaching and then the pulp is neutralized with sulphur dioxide.

Antibiotics

The production of antibiotics continued on the upswing during the year. Penicillin, a war-born drug, was already well established, and possibly the most important newcomer to the scene was streptomycin (31). Streptomycin is obtained from the metabolism of a species of myces. It was discovered by Dr. Selman A. Waksman, of the New Jersey Agricultural Experiment Station, as a result of tests on the antibacterial activity of soil organisms. Streptomycin is a complement to penicillin. Penicillin has specific power against gram-positive bacteria, but streptomycin is effective against the gram-negative bacteria. Infections by this type of bacteria included: urinary tract infections; hemophilus infections including meningitis, pneumonia, middle-ear disease; typhoid fever, dysentery, acute undulant fever, tularemia; bacterial endocarditis

One of the characteristics of streptomycin is its stability when exposed to ordinary temperatures Penicillin is destroyed fairly rapidly under the same conditions. The manufacturing of streptomycin is quite similar to that of penicillin (32) and several large plants for its production have already been built in the United States. A new insulin compound was also reported in 1947 (33) which promises relief for diabetic sufferers. The new compound does not have to be injected more often than once a day, since it retains its effectiveness twice as long as insulin and it eliminates the danger of an undesirable protein reaction. The material, developed at the Chicago Medical School, is ammo-choline-citrate-insulin-hemochromogen.

New drugs were reported for combating high blood pressure (34), and their use holds promise for relief of human beings from this disease.

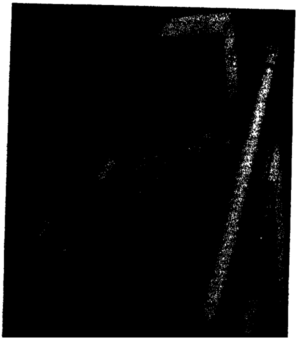
Synthetic Vitamin A

Commercial production of synthetic Vitamin A was announced by Distillation Products Inc., of Rochester. Up to now the only commercial source of Vitamin A has been fish livers. Large scale output of the vitamin, essential for proper growth and vision, is now ex-

Sulfolanes are manufactured in this semi-commercial plant; hexylene glycol batch-still in center.

Typical of Pacific Coast expansion is this new chlorine-alkali plant in Portland, Oregon.

Modern engineering goes into pharmaceutical plants for producing theobromine.



pected, since the process enables it to be obtained in pure crystalline form.

Carbon Black

A new process for making carbon black was introduced by the Columbia Carbon Company (35) which consists essentially of introducing relatively cold hydrocarbon gas by means of several jets into a furnace containing gases that are already burning. The mixing of the two gases results in a quick interchange of heat, and the production of minute carbon particles. These particles are collected by Cottrell precipitators, and further separation is effected by cyclone collectors

Radioisotopes

The Atomic piles were used during the year to produce relatively large quantities of radioactive elements and isotopes More than 100 different radioisotopes were shipped by the Atomic Energy Commission. These were made from sixty different elements, and they are produced either by inserting small amounts of elements into the chain-reacting pile, or by the bombardment of the material by neutrons The radioisotopes are shipped to purchasers in a wooden box within a lead shield Inside the shield is a stainless steel cylinder containing a glass package of the radioactive material The uses of radioactive isotopes in industry are large The petroleum industry has used these substances for oil well logging Metallurgists are using radioactive metals to study various research problems, and there is a great deal of investigation, by means of radioactive compounds into the manner in which chemical reactions go forward (36) Medicine and cancer research are other large users of these substances.

Insecticides

A potent new insecticide which vanishes soon after it completes its lethal mission, was developed by two scientists from the United States Department of Agriculture (37) The original discovery was made by the Germans, but the development announced in this country constitutes an improvement upon what they had done. The compound is tetraethyl pyrophosphate. The workers found that this compound was the potent ingredient in the German material hexaethyl tetraphosphate. It was produced as an off-shoot of research on war gases

New Solvents

A new group of synthetic solvents were described (38). These compounds are hydrogenated forms of sulfones, and are made by the Shell Chemical Corporation. The advantages claimed for the new solvents, as compared to materials now used, are high selectivity, low corrosivity, and chemical inertness.

Allyl Alcohol

The Shell Chemical Company has also revealed their method of making allyl chloride and allyl alcohol from propylene (39) by a continuous process. The principal use of allyl chloride is in making organic compounds, pharmaceuticals, perfumes, and flavorings. The chloride is manufactured by the chlorination of propylene in the vapor phase, and separation of compounds formed. Allyl alcohol is manufactured by the hydrolysis of the allyl chloride.

Underground Gas Storage

One of the techniques perfected by chemical engineers, some time ago but announced for the first time during the year (40), was the storage of coke-oven gas in sandstone strata. The Clairton By-Products Coke Works, seeking for a way to store coke-gas during periods of overproduction when the steel corporation had no use for the material, bought the McKeesport natural gas field for the storage of its excess gas. Before the gas could be stored in the sandstone strata of the field, a resin or gum, created by the reaction of the nitric oxide, oxygen, and diolefines in the gas, had to be removed through the application of known chemical principles. The gas was treated by a process especially developed and installed in a gum treating plant, and then it was pumped underground. The efficiency of the operation in removing the gum has prevented any clogging of the porous earth strata, and several billion cu ft of excess coke-oven gas has already been stored and removed from the field without any loss.

Solvent Purification of Fatty Acids

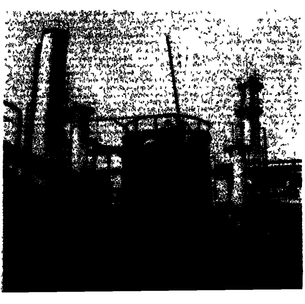
A process for the preparation of commercial stearic and oleic acids, the first important technological advance in this industry in many years, advanced to the operating stage (41). The principal raw material used in the process is the mixture of free acids obtained in splitting natural fats. The stearic and oleic materials are present in this mixture, and heretofore, the two acids have been separated by mechanical pressing. For the first time in a commercial process, pure fractions of these acids can be obtained. The solvent process is based on fractionation of the acids from a polar solvent. Two plants are now in operation capable of processing 30 and 40 tons of material. The original substances which the process can use is not limited to that obtained in the splitting of animal fats, but it can separate greases, linseed, soy bean, and other oils. Briefly, the process consists in proportioning and mixing the raw material and methanol, and pumping the solution through a crystallizer. The crystallizer is refrigerated and a slump is found. The slurry is filtered on a rotary vacuum filter which removes, as a bulky solid, a cake which contains some methanol solution which passes through the filter. The two fractions are then distilled, and purified in individual stills. The cost of producing the acids by the solvent method is said to be less than that of the ordinary mechanical pressing operation.

Another solvent extraction process was announced by the M. W. Kellogg Company. The process called Solexol uses propane under relatively low pressures. The principle of the operation, however, is different from most, for as the temperature of propane is increased, its ability to dissolve the high molecular weight components in an oil decreases. At the critical temperature of propane, only a light oil fraction is left in the solvent layer. A use announced for the process during the year was the refining of fish oil for the recovery of its vitamin constituents. Out of 100 lb of sardine body-oil, the process fractionated out 10 lb of Vitamin A and D concentrate, 35 lb of drying oil fortifier, 45 lb of linseed oil replacement, 3 lb of stearine for use in shortening, 1 lb of fatty acids, and 3 lb of residual material. From 100 lb of soy bean oil, there were obtained 68.5 lb of high quality salad oil, 30 lb of quick drying paint oil, and 1.5 lb of lecithin and other products. A large plant for the recovery of Vitamin A from shark liver oil was built in South Africa at Simonstown (42). Sharks and ling cod are abundant in South African waters, and will provide the raw materials for the plant. The oil will have a potency of 500,000 international units of Vitamin A per gram. The oil left over when the vitamin is removed is expected to yield glycerine for poultry and animal feed, or oils for the manufacture of printing ink, linoleum and leather. The same process was put in by the Lever Brothers Company at Baltimore for refining fats and oils. The plant will use crude tallow as a raw material, and will produce a refined product.

Antioxidant for Vitamin A

The destruction of Vitamin A due to oxidation is a problem that has faced manufacturers for many years. Work was done toward solving this problem (44). It was found that two forms of tocopherols were effective in inhibiting the degeneration of the vitamin. 1/10 of 1 per cent of tocopherols was found necessary. Lecithin

Growing demand for antifreeze will be partly met by ethylene glycol from this new midwestern plant.



Chain driven dryers in a new continuous solvent extraction plant for obtaining oil from cottonseed.

at a 1 per cent level was found to enhance the effectiveness of the antioxidants.

High-Calcium Lime From Dolomites

There was a shortage of high-calcium lime which caused some concern during the year to those who used the material for neutralization of acidic wastes (43) There was considerable work done on the utilization of readily available dolomitic limes, which proved successful if certain precautions were taken The dolomitic limes have a slower reaction rate as compared with high-calcium limes, but through providing an excess of lime and increasing the temperature of the waste, the raw materials were proven to be satisfactory.

New Process For Gluten Separation

The starch industry witnessed the introduction of a relatively new procedure In making cornstarch in the past, the gluten has been separated from the starch by passing the materials over a starch table. Centrifugals were introduced into the industry for separation of these two materials just recently, and have met with great success In operation, two centrifugals are placed in series. The crude mill starch goes to the first, which removes the gluten in the overflow The suspension emerging goes to the second centrifuge, which then produces the finished starch, the overflow being circulated back to the crude mill starch Washing takes place during the centrifuging. The increased starch recovery accruing from this new process is from 85 per cent on the conventional starch table, to about 97 per cent with the centrifuge Another advantage claimed for the method is that it accomplishes the separation in about 3 to 5 minutes, instead of 10 to 12 hours (45).

New Solvent From Butane

Thiophene, a new industrial chemical, was being made by a process which promised large quantities of this material (46). The process was perfected by the Socony Vacuum Oil Company. Essentially it is a dehydrogenation of normal butane using sulphur as the dehydrogenation agent This step is followed by a cyclization with sulphur which forms the thiophene ring. Thiophene is reported to be an excellent solvent, and it will find extensive use in the pharmaceutical industry, in the manufacturing of dyestuffs and resins, and in the textile field.

Illustrations for this chapter appear through the courtesy of the American Institute of Chemical Engineers, American Society of Mechanical Engineers, Standard Oil Co (N. J.), Federal Power Commission, M W Kellogg Co, Dorr Co, Dow Corning Corp, Permutit Co, California Research Corp, Mathieson Alkali Works, Merck & Co, Inc, E R. Squibb & Sons Co, Cutter Laboratories, Shell Development Co, Pennsylvania Salt Mfg. Co, Monsanto Chemical Co, Wyandotte Chemical Corp, Allis-Chalmers Mfg. Co.

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CHAPTER VI

COMMUNICATIONS

by MEADE BRUNET

Predictions made during World War II to the effect that technological advances in military communications would be reflected in post-war progress already have been realized in many phases of communications serving the public Since V-J Day, the process of reconversion has gone forward mainly as planned, but continued shortages of components made it difficult for many months to attain and maintain the schedules of development and production which had been outlined during the closing months of the war Gradually, however, these obstacles have been overcome and prospects for reaching normal rates of progress have become steadily brighter.

Distinct advances have been made in the direction of compressing the globe into *One World* through electronic improvements in telephony, radiotelephony, transoceanic cables and radiophoto systems, and in the multitude of component parts which make possible their functioning

Domestically, the installation of telephones has continued at a mounting rate and phone service has been extended to some remote settlements through the use of radio links connecting homes with existing exchanges Television program services have multiplied as new transmitters, radio relays and cable facilities became available, and frequency modulation (FM), after a period of lethargy, commenced to impress the buying public with its tonal superiority and comparative freedom from static interference

Telephony and Radiotelephony

International radiotelephony and radiotelegraphy continued to expand to reach more countries with faster service of improved accuracy. The inauguration of mechanized systems (1) to handle radiograms with a minimum of manual labor not only has resulted in speeding traffic, but has insured almost error-free transmission (2)

Interruptions of service due to atmospheric interference have been greatly reduced by the installation of semi-automatic relay stations One such station at Tangier (3) permits messages addressed to Moscow, Stockholm and Bombay to "turn the corner" and reach the terminals in those important business centers without encountering the *black-out* intervals that prevail at certain times on direct routes.

At the beginning of 1947, telephone installations reached an all-time high in the United States, with more than 30,000,000 phones connected and with 2,000,000 applications for service on file (4).

Paralleling this increasing demand, continuous research in telephony has further extended the interconnecting of millions of telephones in homes, business offices, commercial vehicles, ships and trains (5).

Open pole lines carrying spans of wires are gradually giving way to cables, some of which are suspended above ground, others buried in covered trenches. Each of these cables may contain up to 2,100 pairs of wire Refinements in cable manufacture have materially reduced the cost of cable installation The standard 50-pair cable cost more than $150 per pair-mile to install in 1888. Today's 2,121-pair cable can be installed at a cost of about $12 per pair-mile (6)

Coaxial Cable Developments

One of the most important advances in telephony is the coaxial conductor and the subsequent coaxial cable. Basically, the coaxial unit is a copper tube about 3/8" in diameter with a single wire suspended in the exact center of the metal sheath Two such units will carry hundreds of telephone messages simultaneously, or two television programs One of the latest types of coaxial cables contains not only eight coaxial units but a number of additional conductors, singly and in pairs, all enclosed within a lead sheath

Although halted by the war, placement of coaxial cables—mostly underground—has since been actively resumed At the beginning of 1947, 2,700 miles already were in the ground These circuits extended from New York down the east coast to Florida and part-way across the Gulf states Another 3,000 miles will be added by the end of this year By 1950, it is expected that 12,500 route-miles will have been completed The nation will then be linked from coast-to-coast, together with numerous coaxial feeders leading off main routes.

Looking to the future and the possibility that television will require constantly greater facilities, engineers point out the extreme flexibility of the coaxial cable As advances in television technique demand still wider

Laying coaxial cable involves a train of rooters, cable-laying plows, cable reel and a bulldozer to replace dirt.

Above is a cross section of coaxial cable. At the left the cable has been stripped in sections to show the successive layers. 2 of the small circular conductors can carry nearly 500 telephone conversations. Below is shown a map of the United States with the coaxial system installed, under construction or planned. The conductors are protected by polyethylene disc insulators.

frequency bands in order to obtain finer picture detail, existing coaxial cables will not become obsolete. To handle these broader frequency bands, only the amplifier equipment at *repeater* points will need to be replaced. Presently, coaxials are transmitting frequencies up to about 3 megacycles in band-width It is expected that new amplifiers will advance this limit to 7 megacycles, possibly higher.

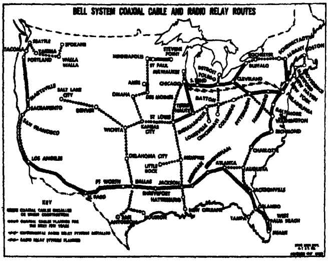
Mobile radiotelephone service is now operating on a commercial basis (7) Up to mid-year, nearly 100 vehicles, both trucks and private cars, had been equipped with two-way apparatus To care for this message traffic, fixed-stations were established to serve as connecting links between mobile subscribers and existing telephone circuits and exchanges In the New York area alone, 120 fixed-station units were installed to serve the mobile stations The telephone company retains property rights to the radiotelephone gear and the automobile owner pays a monthly service charge of $22 This sum covers 120 *message units*, each unit being based on time and distance of call. Six to eight units are expended in an average call (8).

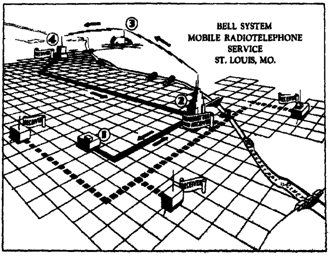
Commercial telephone service between moving trains and any telephone subscriber is available to travellers on certain express trains running between New York and Washington (9) Operation of these circuits is identical with that of the land mobile service, with a two-way transmitter-receiver unit aboard the train making contact with fixed-stations erected at necessary intervals along the right-of-way.

Realizing the advantages of intercommunication between locomotive and crew of trains, between trains and also between trains and control towers, many railroads of the United States have installed very high frequency (vhf) radiophone systems with generally satisfactory results (10, 11)

It has been estimated that nearly one fourth of the nation's railroads are using radiotelephone equipment One road alone—the Atchison, Topeka and Santa Fe—is operating more than 130 mobile units and a number of land stations

Taxicab fleets in some cities are operating more efficiently and giving better service through the use of two-way vhf systems. With each driver in constant touch with the dispatcher's office, not only can the cabs





be shifted from one area to another as demand changes, but less time and fuel are lost in returning to the cab-stand after completing each call

Party-line radiotelephone service as an adjunct and feeder to existing wire telephone for remote rural areas has been tried out in Colorado with favorable results (12, 13) In this system, the subscriber is supplied with transmitter and receiver units operating in the 44-50 mc band Lifting the phone from its cradle automatically energizes the apparatus and generates a radio signal which notifies the telephone operator that a connection is desired

Expansion of rural telephone service using power lines as a carrier has been underway since the first of the year First areas to be served in this manner are in Virginia, North Carolina, South Carolina, Texas, Colorado and Washington At the outset, the equipment for each of the power lines routes will provide one channel for telephone service with six subscribers on each channel Eventually, apparatus will be available to furnish six speech channels on each power-line route (14).

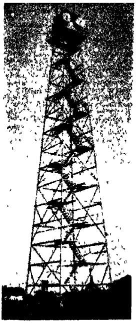
Telegraphy

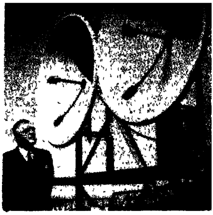
Domestic telegraphy has made progress through the institution of two technical developments, viz, the wide-band beamed microwave radio relay and the push-button system of speeding message traffic (15, 16)

The triangle formed by New York, Washington and Pittsburgh was selected as the site of the first service trial of beamed relays for telegraphy The first leg of this triangle — New York to Philadelphia — required booster stations near Bordentown, N J, and New Brunswick, N J, with an average link-span of 28 miles Between New York and Washington there are seven repeater stations

Using a band of channels 150 kilocycles wide, and operating on the 3,900-4,000 megacycle band this relay system will handle 576 telegraph messages simultaneously By beaming the microwaves from one repeater station to another, it is possible to deliver as much signal with a 0.1 watt transmitter as could formerly be accomplished with 250 watts at the transmitter The booster units are automatic and unattended and the operating condition of the transmitters and receivers is known at all times to attendants at terminal points through information transmitted over a *service* frequency.

Using different frequencies a carrier system sends as many as 288 telegrams over a pair of wires or 1,024 messages over a radio beam simultaneously.





Reflectors, like the pair shown above, with radio antenna at their center, are used to relay telegrams from one radio beam telegraph tower (at left) to another.

Transmitting as many as eight telegrams over one wire by the multiplex system.

Telegraphy Relays

As the relay systems come into greater use in overland telegraphy, they will displace thousands of miles of familiar pole lines and hundreds of thousands of miles of telegraph wire Yet their cost over a 7-year period is estimated to be less than the cost of maintenance and reconstruction of the pole lines they will replace.

Beginning late last year, telegrams routed through Philadelphia to key points throughout the country were handled automatically by a push-button system which triples the message-handling capacity of the Philadelphia center (17).

Under this system, a telegraph message is typed only once, at the point of origin. At Philadelphia, the message appears on a printer perforator which simultaneously prints the message and punches combinations of holes in a paper tape. As the clerk reads the message and notes its destination,—San Francisco, for example—he presses a button representing that city. This action causes the perforated tape to operate an automatic transmitter on the San Francisco circuit At the latter city, the signals appear in printed form ready for delivery.

Automatic Telegraph Transmission

A development that is expected to receive public acceptance is the automatic telegraph transmission and reception system called Telefax In this system, the message to be sent is typed or written in longhand on a standard telegram blank which is then dropped into the slot of a coin-operated console Within the console a mechanism wraps the blank around a rotating cylinder and a scanning beam of light transmits the message line-for-line to the receiving station.

Already in use by some large organizations including airlines and railroads, Telefax receivers are to be installed in hotel lobbies, railroad terminals and other common meeting places

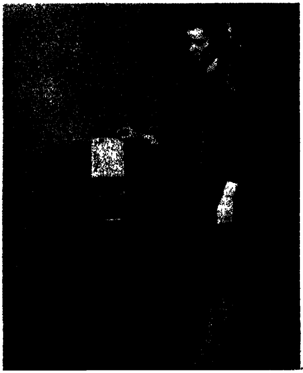
During the past year, several important developments have taken place in Facsimile, particularly in its adaptation to special services such as police and forestry departments and railroads.

At Miami, Florida, the *Miami Herald* transmitted a series of facsimile newspapers on regular schedules as a practical test of one system. Each page, 8 inches by 11 inches in size, was transmitted in slightly more than two minutes, with approximately 100 scanning lines per inch.

Color Transmission and Radiophoto

Late in the year, a system of color facsimile was demonstrated, in which colors of the subject matter are separated by filters and then transmitted as impulses representing each color At the receiving end, the impulses actuate color pencils which reproduce the original in its various tones.

Telefax transmits messages automatically. They arrive as facsimile reproductions at their destination.



Radiotelegraph circuits carry words from any part of the world to another with the speed of light but it is common knowledge that nothing conveys facts and creates impressions like pictures.

The war accelerated radiophoto service (18). The public grew to expect today's newspapers with their numerous features and stories illustrated with pictures taken yesterday in Europe or the far Pacific, transmitted by radiophoto Since V-J Day, businessmen have made wider use of this service in conveying legal documents, advertising layouts, financial statements, patent drawings, building plans, etc, across oceans

More of the national governments which control communications within their borders now recognize the trade and advertising value of picture transmission and have adopted a friendlier attitude toward cooperative service To the existing radiophoto links between the U S and England, Germany, Italy, France, Switzerland, Sweden, Austria, Russia, Egypt, Argentina, Hawaii, Australia, the Philippines, India and Korea, will soon be added others to Mexico, Japan and China. It is expected that, eventually, the world will be covered with this form of radio communication

Through the use of vhf radiophoto circuits, photographs of local news events have been delivered to newspaper city rooms within 8 minutes after the click of the newsman's camera shutter (19). A mobile van carries the developing apparatus and a low-power transmitter operating in the 160 m c region After development, the print is wrapped around a rotating cylinder and scanned in the usual manner, the output of the photo-cells modulating the fm transmitter.

Increased speed of ocean cable telegraphy has been obtained by putting into operation some wartime developments (20) Conversion from cable code recorder operation to 5-unit code printer operation and the refinements of relays and their associated components are largely responsible for the improvements. It was reported that one cable is operating practically continuously between New York and London at 400 words a minute.

The International Telecommunications Conference which convened at Atlantic City in May, 1947, adjourned on October 2nd. Delegates from 78 nations attended (21). The development of new communications services such as radar and loran, and the normal expansion of existing services, particularly marine communications, posed difficult problems to the degelates in their attempt to spot these services in an already overcrowded frequency spectrum. One of the important tasks before the Conference was the organization of the International Telecommunications Union and the establishment of its relationship to the United Nations (22, 23).

Television

First concrete evidence that radio manufacturers and the public were mutually ready to launch television on a scale beneficial to both groups appeared late in 1946 At that time, the first postwar television receivers reached the market in quantities sufficient to attract attention (24) Since then, monthly production has increased, more companies have entered the field, a large number of stations have applied to the FCC for construction permits, and a wider variety of set models has been turned out to appeal to different buying levels

Television service is now permanently assigned to the so-called upper band of frequencies The FCC has allocated 13 channels, each 6,000,000 cycles in width, for commercial television stations Beginning at 44 megacycles these channels occupy the spectrum to 216 megacycles, with the exception of a few channels allotted to other communication services

In November, 1947, 15 television stations were operating on regular schedules (25) They were supplying programs to the urban and suburban areas centering in New York Philadelphia, Baltimore, Washington, Schenectady, Albany, Detroit, Chicago, St Louis, Cincinnati, Los Angeles and Milwaukee By the year's end, 6 or more additional transmitters were scheduled to be in operation

For remote pick-ups of television programs from points a few miles from the transmitter, microwave relay systems operating in the 6,800 to 7,000 m c band have been developed and are already in use (26) An overland microwave relay connecting New York with Boston was demonstrated on November 13 Intended primarily for telephone traffic, the wide frequency band of the latter system will also make it suitable for television transmission Since the operating characteristics of the coaxial cable as a conductor of television signals are now well known, test results of the N Y -Boston relay link will permit engineers to compare the relative effectiveness of the two methods of channelizing video signals

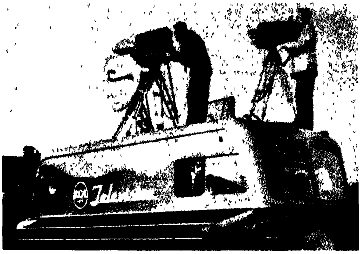
Large screen television systems (27), providing images up to 7½ by 10 feet have been publicly demonstrated To obtain pictures of this size, adequately lighted, engineers developed a small cathode-ray tube called a kinescope, only 5 inches in diameter and working on voltages up to 60 kilovolts, and an optical system based on the Schmidt astronomical camera (28, 29).

After exhaustive hearings at Washington and in the field, the FCC ruled that color television (30, 31, 32), despite its demonstrated progress, should be returned to the laboratory for further development (33)

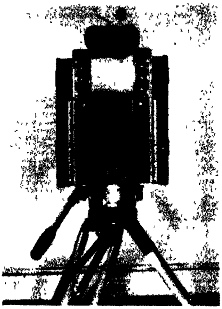
With the release of restrictions on essential building materials, the construction of standard radio AM and FM stations established a new high during 1947 Several hundred backers of projected AM stations who had been awaiting the unfreezing of construction by the FCC, started to plan the erection of studio and transmitter buildings in May (34). The majority of these projects became realities, with a total of nearly 1500 standard broadcasting stations being scheduled for operation by December. This compares with approximately 650 on January 1, 1941.

Frequency Modulation

Although activities in FM (frequency modulation) have increased, this type of broadcast service has yet to



Newly developed mobile television unit facilitates news coverage and remote pickup operations.



Rear view of RCA Image Orthicon Television Camera showing the controls available to operator.

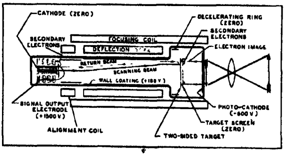
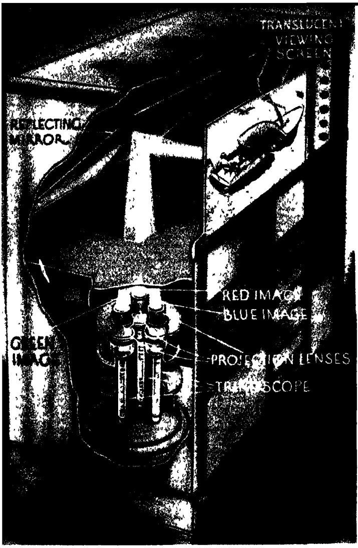


IMAGE ORTHICON

Cross section of television camera tube showing how the scanning beam is projected from the cathode (at extreme left) toward the target at the right, on which electrical charges have been built up for focusing an image of the scene on the photo-cathode The scanning beam is given just enough velocity to reach the target. If the electrons in the beam strike a positive charge they are absorbed. If the target charge is negative, electrons in the beam are returned to area near cathode. There they strike the first dynode generating secondary electrons These electrons in turn strike other dynodes, greatly increasing the total number of electrons and hence the current carrying the picture information



Television receiver showing images of 3 kinescopes of the trinoscope being projected from mirror to screen.

Experimental commercial service for two-way highway mobile radio-telephones has been inaugurated. Operator here is talking to his office, 15 miles away.

fulfill the hopes of its most optimistic adherents, due to a combination of factors Manufacturers of FM transmitters faced a continued shortage of copper and other essential metals, and for similar reasons, receivers were slow in reaching dealers' shelves from the production line Furthermore, the listener, after purchasing an FM receiver often learned for the first time that FM broadcasters were not permitted by the musician's union to transmit live music This ban forced program planners to rely almost exclusively on records and transcriptions.

One of the noticeable technical advances in FM was the introduction of the *ratio detector* which made possible the production of receivers at lower cost (35, 36) FM tuners and adapters, designed for attachment to existing AM receivers, served to hasten the building of audiences in areas served by FM transmissions

An FM network, utilizing a combination of 8,000 cycle telephone cables and direct over-the-air transmission from key stations, has been functioning on the eastern seaboard since mid-summer of 1947 on a limited scale (37) For longer links between stations, the Bell System has indicated that Class AA wire lines capable of transmitting a band-width of 15,000 cycles will be made available in some parts of the country (38).

New Electronic Tubes

Back of every important wartime electronic development was the vacuum tube Several hundred new types were designed for military purposes (39), and from the problems met and solved in this research there emerged several new tubes with definite peacetime application to communications

The cavity magnetron (40), heart of the radar, is invaluable in microwave relay circuits and in air navigational systems Further, the apparent ability of this tube to operate at still higher frequencies as the result of research will create additional uses for it Magnetrons are now available with frequency-handling characteristics that are reaching down into the centimeter band (41) Where brief pulses of high power are required, the magnetron is unexcelled (42) Types have been developed that will generate hundreds of kilowatts for a small fraction of a second (43)

A new tube, working on new principles, has extended both amplifying power and band width Called the *traveling wave tube* (44) because of the manner in which electrons pass up the length of the tube, its early tests hold hopes that it will accommodate the signals of several scores of television stations simultaneously Along its extremely broad band of frequencies, it should be possible to space thousands of telephone conversions without mutual interference.

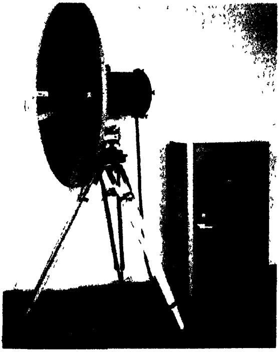
In the field of radio broadcast receivers, the tendency is toward the miniature tube (45). Know-how acquired during the war in designing multi-tube apparatus in compact dimensions has been applied to standard tubes in peacetime. As a result, radio set manufacturers now have complete lines of highly efficient miniature tubes which give improved performance in a minimum of space.

The increased interest in FM has led to the development of several types of transmitting antennas designed to function in the 88-1-8 m.c. band. Included are the *Pylon* (46), one of the numerous forms of slotted cylindrical radiators (47), the *clover leaf* (48), the *loop* and the *box*, the last three being variations of the turnstile (49, 50) Some experiments were carried out on antennas which polarized waves circularly (51) More uniform coverage and improvement in signal-to-noise ratio were some of the advantages claimed by adherents of this method of signal propagation

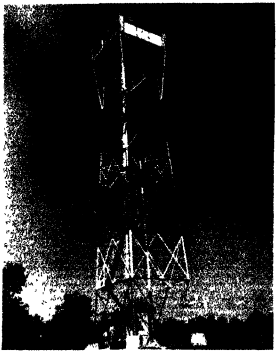
Printed Circuits and Resistors

First used in fabricating the radio proximity fuse in the latter days of the war, the printed circuit holds promise as a means of reducing cost and size of certain radio components, particularly audio-amplifiers for small units (52) The circuit is printed or stencilled on a sheet of insulating material—usually steatite ceramic—using a silver compound in paste form The combination is then baked at high temperature to produce a close bond

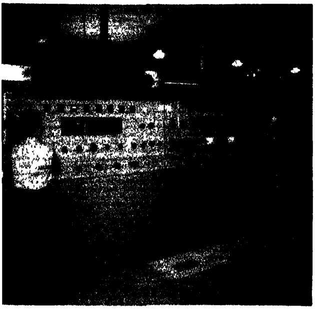
Resistors are incorporated in the printed circuit by spraying the resistance material through masks onto the steatite base (53), capacitances made of ceramic disks are soldered direct to the silver leads Some success has been reported in forming uhf coils on the steatite, using the same procedure



Microwave receiving equipment for frequencies of 6800 to 7050 megacycles and for distances up to 20 miles.

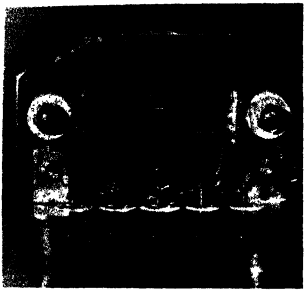


One of the relay towers in four-link microwave relay system between New York City and Schenectady.

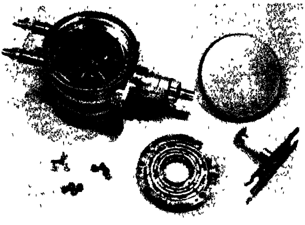


Making adjustments on new broadcast short-wave transmitting unit recently installed for RCA transatlantic service.

Control room for Bell system overseas radiotelephone services with panels for European and South American areas.



4,000 megacycle CW magnetron is frequency-modulated by beams from two tiny electron guns attached to the anode structure.



The 1-kw CW magnetron is assembled from parts which provide ease of construction as well as great reliability.

Illustrations for this chapter were obtained through the courtesy of American Telephone & Telegraph Co., Bell Telephone Co., Western Union Telegraph Co, and Radio Corporation of America

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CHAPTER VII

COMPRESSED AIR

by ED C POWERS

Man's economic progress through the ages might be measured by the advance from the crude bellows of primitive days to the blower-type air compressors he fashions today for use in the Bessemer process of converting pig iron to steel But equally significant is the way man has expanded the applications of compressed air We ride on tires inflated with compressed air, much of our food is prepared with the aid of compressed air, and few are the products used in our daily lives to which compressed air has not contributed in some way

Industry relies on compressed air power to perform an almost unlimited number of tasks All of the wide and varied uses cannot be mentioned here, but some typical applications of compressed air presented here may suggest how factories and mills working with metal, wood rubber, plastics and other materials are benefitting by its use

Acid and Chemical Works (1)

The simplicity and effectiveness of the agitation of liquids by compressed air explains its widespread use in this field Usually an air line is run along the bottom of the tank, where the lower side of the pipe is perforated at intervals to release air pressure No investment for mechanical apparatus is required and the harmful effect of many acids on mechanical apparatus is eliminated

An application is illustrated in Fig 1 (2) Similar applications are found in many other industries, including the small tanks of solutions used by garages and machine shops for cleaning metal parts

Pumping water and chemical solutions, or elevating and transporting them by pressure are other common applications for compressed air Tanks and pipe lines are caulked by air hammers and air pressure is applied in testing them

Agriculture

There are many uses for compressed air in the cultivation and processing of food, handling of livestock and farm maintenance Fruits and vegetables are being dehydrated in ever increasing volume and this work involves the maintenance of a vacuum, which means compressing air up to atmospheric pressure

Other typical agricultural applications for compressed air include air-operated systems for lubricating equipment, inflating tires on tractors and trucks, spraying of insects, feeding livestock in transit, protecting dams against ice, handling rice hulls, combating forest fires, leveling sand dunes, cleaning eggs by sandblast, picking raw cotton and harvesting broom roots with pneumatic diggers.

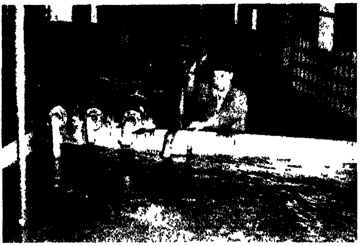


Fig. 1. Sulphuric acid, diluted with water, is agitated by pressure from an airline along the bottom of the tank.

Manufacturers and dealers in implements also make extensive use of compressed air to operate air hoists, for sandblasting metal parts to clean them of scale and paint and for many air-operated tools such as drills and pneumatic hammers (3)

Aircraft (1, 5, 6, 7, 8, 9)

Several hundred thousand rivets and nuts go into an airplane One engine nacelle for a four-engine plane has 1300 subassemblies intricately fitted Air-operated drills, wrenches and riveting hammers are used for this work because the tools are lightweight yet powerful and can be used constantly without overheating

Large jigs for wing flaps, wing spars, and other assemblies for modern planes, hold these aircraft assemblies while dozens of workers at each jig complete assembly work with the same type of air tools used on the engine nacelle Presses, metal brakes, spar mills and other machines used in making aircraft parts are frequently controlled by air power Spray painting of parts and fittings is done with air guns and compressed air-operated hammers planish wrinkled aluminum parts In the production of aircraft engines, the applications for compressed air are similar to those for other types of machinery.

Automotive Industries (10, 11)

From manufacture to regular maintenance of the automobile, bus or truck, compressed air plays an important role Air-operated impact wrenches, grinders, drills, reamers, buffers and pneumatic hammers are hand tools commonly used in factory and garage, a typical application being shown in Fig. 2 (12).

Air chucks, air-operated tail stock for safe and quick travel, and other air devices, are used on machine tools where high rate of production is a factor Air hoists to take heavy pieces to and from the machine are fast-acting, easy to control, avoid physical strain on the operator and prevent dropping and spoiling of machined work Air hoists, which do not spark, are preferred where inflammable material is being handled

Most people have seen the applications for compressed air in automobile servicing, which include tire inflators, air lifts, air jacks, pneumatic grease guns, and air jets to clean engines, blow out clogged gasoline lines and clean car interiors Air guns for spraying paint, or oiling springs, or anti-rust solutions are others Compressed air is also employed in starting engines, regrooving solid rubber tires, sandblasting and cleaning pistons, and sandblasting spark plugs Agitating solutions for cleaning metal parts is still another use

Fleet operators who maintain special facilities for repair and restoration of their motor vehicles use compressed air in the ways mentioned and for additional applications (13) Metallizing worn parts, such as the crankshaft in Fig 3, is done with the aid of compressed air (14) In machine shops, applications of compressed air are the same as many of those mentioned under metal working and machinery

Cement Production and Products

The Portland cement industry is one of the largest consumers of compressed air and probably no industry surpasses it in diversity of application

The largest proportion of the compressed air requirement of a cement plant is utilized in conveying (15-16) All but a negligible proportion of the Portland cement manufactured in the United States is transported from grinding mills to storage silos by compressed air pumps Many mills also utilize the compressed air pumping method for conveying cement from silos to packer bins, for loading and unloading cars, and for unloading and loading barges and ships (Fig 4) Kiln flue dust, packer spill and pulverized coal are frequently handled in this manner.

In many dry process plants, the raw materials are both conveyed and blended for precise chemical control of the composition, by compressed air pumping and aeration

In wet process plants compressed air is utilized to mix and blend the slurries and to maintain the individual mineral particles in intimate mixture and suspension To decrease fuel consumption in burning, many mills dewater the slurry by filters served by vacuum pumps

Aeration of bins, to insure free flow and discharge of dry pulverized materials, is universal practice throughout the industry

Rock drills are essential in cement plant quarries, and most crushing departments employ compressed air rock hoists and car dumpers Air-operated grinders and other tools are commonly used in the large maintenance shops which cement plants require, and compressed air and vacuum lines are essential to plant laboratories

Large volumes of air, at fan and blower pressures, are required in cement manufacturing Blowers, or fans, supply the fuel or primary combustion air stream to kilns which are usually fired by pulverized coal or oil The use of air-swept unit mills for pulverizing coal is rapidly increasing Air in large volume and at fan pressure, quenches the hot clinker, reducing its temperature abruptly from about 2500 degrees F to about 150 degrees This improves cement quality, recovers heat and reduces the clinker to a temperature suitable for grinding Most modern plants employ air-swept pulverizers in closed grinding circuits to control cement firmness and to economize in power Similar circuits are used in dry process plants for the preparation of raw materials Fans serve dust collectors in almost every department of a modern cement plant

One concrete products plant reports a 25 per cent increase in production and a greatly reduced labor turnover by installing the type of air hoist illustrated in Fig 5 (17)

Construction (18, 19)

In the great construction industry, compressed air is found at work from the time ground is first broken through to the final stages of construction, and then again in the regular maintenance of the completed structures In constructing bridges, roads, dams, (see Fig 6), structural work, sewage and trench work, buildings and building remodeling, tunnels and in practically all other types of construction, compressed air is helping in some way to do the job better and faster

Fig. 2. Automotive manufacturers use a large variety of air-operated tools on almost all assemblies.

Fig. 3. The worn surface of this camshaft is built up by applying melted metal with an air spray.

The paving breaker was among the first of pneumatic tools to find widespread use One man with this tool can do the work of 15 working with hand sledges and chisels in cutting asphaltic or concrete pavements, or demolishing concrete foundations, retaining walls, floors, partitions, etc

The same reciprocating action of the paving breaker is employed in pneumatic tools, of varying size and construction according to their purpose, in rock drills (20), chipping hammers, caulking and riveting hammers, and other air-powered tools

Bridge builders and structural steel workers use compressed air-operated tools for chipping, riveting and caulking Drills, reamers and punches are other types of air tools used Air hoists are used to raise tools and materials to workers above the ground Cleaning steel by sandblasting, blowing rivet forges and smith fires, and spray painting are other common applications for compressed air

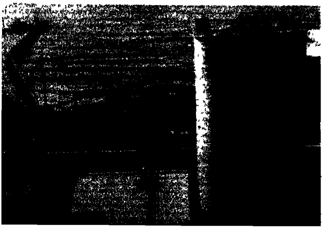
In road and highway construction (21), compressed air powers many tools In cities, compressed air is the power preferred for many road working devices

Sufficient power is packed into air tools to enable them to perform rugged jobs without being too heavy for the operator to handle There is no overheating from constant use, and tool maintenance cost is low No other form of power is as practical as compressed air for many operations in the construction field Back filling, tamping dirt and concrete, testing and caulking sewage and water pipe lines, operation of drainage pumps, power brushing of pipe to remove rust, driving metal road markers, brushing concrete surfaces, sheet pile driving, caisson work, casting concrete piles, drill sharpening, and cutting metals under water all are jobs for which air-operated tools and equipment are being used by contractors to lower construction costs

Air guns to apply concrete on new construction and repairs are a common application for compressed air Air guns for spray painting are saving time and money on innumerable projects On tunnel projects, air-operated rock drills, clay diggers and other pneumatic tools speed a job to completion (22) Lightweight, air-operated pumps are used by contractors for pumping out sumps, trenches, manholes, caissons, coffer dams, tanks and bilges.

There are other important applications for compressed air on construction, and most of the pneumatic

Fig. 4. Air pumps convey cement from pulverizers to the storage silo. It is then conveyed by compressed air pumps to ocean going vessel approximately 3600 ft. away.



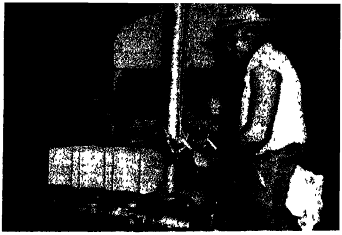


Fig. 5. Concrete blocks coming out of the vibrator machines are so soft that they crumble Starting and stopping jolts from hoists operated by chain or cable proved impractical. The smooth action of piston-type air hoists eliminated the need for moving the 35-lb wet blocks by hand.

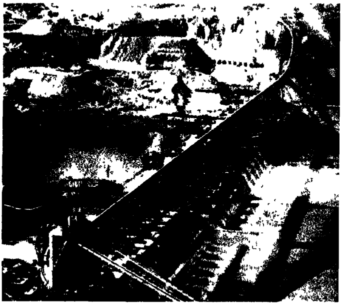
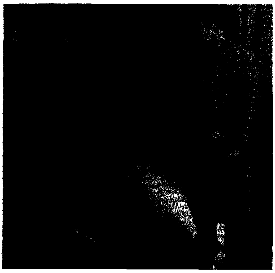


Fig. 6. Cement on the Grand Coulee Dam was conveyed by cement pumps, through one continuous pipe line, a distance of about 1¼ miles. White line indicates approximate location of cement pipe line from blending tanks (upper left) to mixing plant (lower right).

Fig 7 Pneumatic conveying system is used for unloading and conveying malt from box car to storage.



tools innumerated have a number of uses in addition to those specifically mentioned The typical applications for compressed air which are listed can only suggest work which this versatile power can perform successfully.

Food Industries (23, 24)

Packers, bakers, millers, refiners and many others in the food industries are applying compressed air to quicken daily tasks

Transferring liquids and grain from railroad cars is a common application in most food industries The pneumatic conveyor shown in Fig 7 is capable of unloading a carload of grain in three hours

Sugar refineries and bakeries use compressed air for transferring syrups Vegetable fats and other liquids are transferred in the same manner The agitation of certain liquids or foods such as pickles calls for compressed air Pressure filtering also uses the same source of power

Canneries use compressed air in the ways mentioned, as well as for blowing cans to filling machines, and for cooking and sterilization (25) Bakeries use air for cleaning biscuit dies (26), spraying butter in pans, and pressing out dough in measured amounts from automatic roll machines Air jets are the best way for cleaning crumbs from bread slicing machines without stopping operations Air hoists and lifts are commonly used in the plant and at the loading dock Vacuum packing is another service performed with the aid of air compressor equipment for the food industry

Foundries (27, 28, 29)

The foundry industry has put compressed air to work in numerous ways. Sand rammers, molding machines, sand sifters, several types of vibrators, and clamps for holding work are air-operated Air hoists and lifts assist in handling work Pneumatic hammers, drills and grinders are used in different operations Castings are cleaned by air sandblasting or air-operated wire power brushes Machines and cores are cleaned by blowing off with air Compressed air is indispensable in a foundry

Gas Works

The compression of gas for high pressure transmission and for other purposes requires many large compressors Small air compressors are used to start gas engines Compressors again are required for compressing carbonic acid, acetylene, oxygen and other gases Compressed air is used for testing pipe lines, and pneumatic tools are used for caulking pipe lines and tanks and for riveting tanks

Fig. 8. A quick way to remove and clean heat exchanger tubes is with an air-operated chipping hammer.

Ice and Refrigerating Plants

Applications here include air hoists for ice tanks and loading cars, pumping and aerating water by compressed air, scaling condenser coils and cleaning boiler flues with compressed air

Lumber

Saw mills, woodworking plants and other lumber plants depend upon compressed air to do much of the heavy work Unloading logs and splitting, cutting, sawing and trimming wood are a few typical applications Wood preserving processes also employ compressed air

Air is used to blow sawdust and shavings from machines and for cleaning rafters timbers and framework Spark-free air hoists are capable of handling heavy loads with speed and ease and such hoists eliminate the fire hazard from motor sparks in the presence of combustible materials

Metal, Metal Working and Machinery (30, 31, 32, 33, 34, 35, 36, 37, 38, 39)

Production of metals and the machines which work them into finished products is a vast field of industry In countless processes from molten metal to the finished product, compressed air performs a highly useful role, sometimes in a minor way and sometimes as the essential factor in the process In the manufacture of wrist watches or washing machines, bolts or battleships—whatever the product—compressed air contributes in some way to production

The Bessemer process for making steel calls for huge quantities of low-pressure air for aerating metal Pneumatic tools are used around the mill for chipping and grinding billets, as well as for tapping blast furnaces. Smelters and ore mills use air hoists and lifts, agitate cyanide solutions with compressed air, and clean cyanide tanks by sandblast Caulking of tanks, blowing converters, operating converter tamping machines and handling solutions are a few other typical applications (40)

In metal working plants compressed air works at heavy and light jobs Riveting, whether with small air hammers on light work, or with bull riveters, is a common application for compressed air

Small air grinders give tool makers and production workers high, variable and easily controllable speeds for hundreds of metal working tasks (41). Larger air grinders are used for removing weld slag, burrs and scale, and for cleaning up work in other ways

The same flexible power which gives air grinders their effectiveness also is applied to drills, wrenches and screw drivers. Ease of handling, power in relation to size, low maintenance costs and ability to operate for long periods without interruption makes these pneumatic tools popular with both workers and management.

Work positioning is an application for compressed air which is helping to lower costs in the metal industries

Entire auto body frames are placed in a jig and clamped into place by a series of air pistons, to hold the assembly true and firm during welding operations Small pieces are held by the same air clamping principle Air motors are used to turn large tanks and other huge containers to the desired working position during construction Air vises are used to hold work firmly and evenly and compressed air is applied to many other work positioning devices

The use of air jets to keep cuttings clear from tools is probably the most common of all applications of compressed air to machine operations

Air chucks on lathes, milling machines and other machine tools reduce the time required to insert and remove pieces of work (42) Air chucks are commonly used instead of the slower manual tightening of work when the cutting time is brief and high production rates are essential

Air motors and air pistons are also applied in many ways to bring work to the tool or tool to the work

Forge hammers and other steam-operated equipment frequently are operated more economically and effectively by compressed air Bending presses, air lifts and jacks, spray painting, sandblasting, pumping water, stamping, planishing and embossing are other applications for compressed air in the metal industries (43) Testing for porosity, leaks or other flaws is done by building up inside air pressure and submerging the part in water Parts are assembled by the use of air pistons Factory drawings and written messages are carried by pneumatic tube systems These applications may suggest the scope of this versatile power and indicate how important compressed air is to the metal working industry

Mining

In mines, compressed air is lightening the burden of the miner and increasing output Pneumatic rock drills are important mining tools (44) Other typical uses for compressed air include: return air system for station and sump pumping; unwatering by air lift system; unloading cars; running direct-acting pumps, loading ore; filling cracks and seams with cement, conveying; ventilating inaccessible areas, pile driving for shaft work; operating coal punchers, chain machines and radial-axe coal cutters; spreading stone dust to prevent coal dust explosions, operating pick and drill sharpeners

Oil Refineries (45, 46)

In production processes and maintenance, compressed air serves the oil industry in important ways.

Backing out heat exchanger tubes with an air-operated chipping hammer is illustrated in Fig. 8 (47). Using the same air motor with different tools attached, the worker also drills out clogged tubes, and brushes and flares the ends of the tubes with a tube roller. Similar but larger air-operated tools are used for cleaning out coke formed in big tubes in the towers. Pneumatic tools also are used in caulking, riveting and other maintenance work on tanks, pipe lines, etc. Sandblasting of towers before welding, air-operated work positioners and air hoists are other typical applications for compressed air.

Packing Houses (48, 49)

Stuffing sausages, testing sausage casings; operating belly pounders, loin presses and shoulder cutting machines, and pumping water are a few of the typical applications for compressed air in meat packing Compressed air aids combustion in smoke houses and is mixed with flames for removing hairs from hog snoots, etc Air hoists are used to lift calves from conveyor lines and for other lifting where speed and ease of the lift's operation is important

Paint Factories (50)

Filling and sealing cans is a typical application for compressed air by paint manufacturers Stamping cans, transferring liquids, dressing burr stones and air lift and hoists are others The absence of sparks in the presence of inflammable varnish is one of the reasons air hoists are especially chosen in handling varnish filters

Quarries (51, 52)

Compressed air is the principal form of power for most quarry operations Stone channelers, rock drills and plug drills all are air operated Steam pumps are operated by compressed air in many quarries because of the ease of delivering power to the pump without great loss Pumping also is done by the return-air system Air hoists and lifts are important quarry aids in handling heavy stone slabs In the smith shop, hammers, sharpening tools and other equipment are operated by compressed air

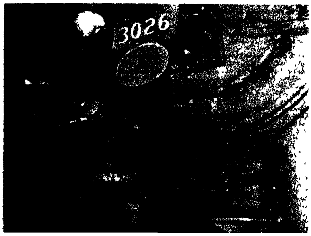
Railroads (53)

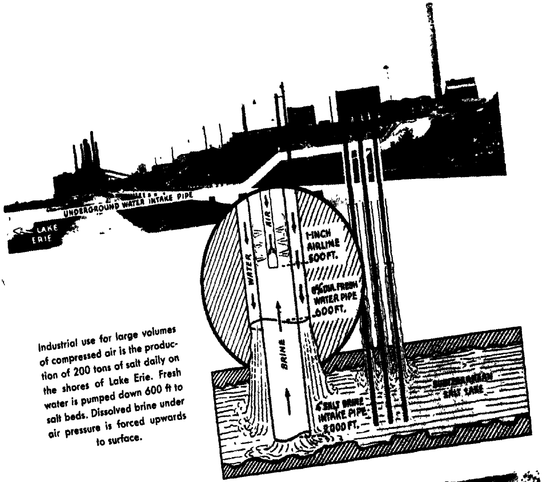
Steam and electric railways have found that hundreds of tasks can be performed best with compressed air-operated tools and equipment Along the tracks, in car shows, roundhouses and railway yards, this important industry is doing essential work with the aid of compressed air (54)

Fig 9 shows a roundhouse boiler maker tightening the boiler door on a locomotive with an air-operated impact wrench.

A few of the many other railway applications for

Fig. 9. The locomotive boiler door is tightly closed with an air-operated wrench. A hand wrench would cause unnecessary exertion and perhaps an accident.




UNDERGROUND WATER INTAKE PIPE
LAKE ERIE
WATER
AIR
1-INCH AIRLINE 500 FT.
6⅝ DIA. FRESH WATER PIPE 600 FT.
BRINE
4" SALT BRINE INTAKE PIPE 2,000 FT.
UNDERGROUND SALT LAKE

Industrial use for large volumes of compressed air is the production of 200 tons of salt daily on the shores of Lake Erie. Fresh water is pumped down 600 ft to salt beds. Dissolved brine under air pressure is forced upwards to surface.

Air hoists find frequent application in metalworking shops to provide lifting power when air supply is available.

Air operated clay digger, with piston stroke of 2.5 to 4 in. is a labor-aiding tool for working clay and hard pan.

pneumatic tools are cutting out boiler flues with air hammers, drilling, greasing locomotives, reaming, grinding surfaces, caulking boilers and tanks and chipping outside boiler seams A mechanized railway track gang uses compressed air-operated tools for driving spikes, digging, grinding rails, tightening bolts, tamping, pulling spikes and other jobs which can be done faster than by manual methods

Air jacks are used to line up locomotive wheels and innumerable other tasks Motors and generators are cleaned with air jets Sandblasting cleans car seats, removes paint and cleans castings Operating cement guns, delivering sand to locomotives, cleaning switches, spraying paint and operating turntable motors are other ways in which railroads apply compressed air to their daily work Grease sticks and wafers are extruded from grease blocks by high-pressure air and flues are cleaned with an air-operated rattler

Rubber

Production of tires and other rubber products calls for compressed air in many of the processes Air blasts are applied for cleaning out tire and other molds Small air drills are used to clean out little holes in the wall of the mold in order to release gases from the heated rubber during vulcanizing Air pistons press unvulcanized casings into the general contour of a tire Air pistons also are used to ram crude rubber into the rolls of mixers

Temperatures for rubber mold presses and vulcanizers are very closely controlled by means of air-actuated instruments, brushing of molds is done with air powered brushes, and testing, disk-spraying, cleaning of rubber goods and inflating of tires are other typical uses for compressed air

Shipyards and Marine (55, 56, 57)

Compressed air has long been an essential factor in building and repairing ships (Fig 10) Pneumatic tools have eliminated many slow, tedious steps in construction Air hammers are used in driving nails and spikes in keel laying, for chipping weld scale, for riveting and for caulking Air grinders have innumerable applications in smoothing surfaces (58, 59) Spray painting is speeding up that phase of shipbuilding to 20 times faster than hand brushing methods Air-operated reamers and drills are other important tools to shipbuilders

Since much of their work is in the open, shipbuilders find compressed air especially convenient and useful in blowing off snow, rain or dirt from work Testing welded seams is made easier by blowing away water accumulated inside the seam Siphoning off rain water with compressed air removes it more thoroughly than pumping.

In addition to its extensive use in the foregoing industries, compressed air is used in ammunition depots (60 61), asphalt refineries, beverage production (62); cigar and cigarette factories, cut stone and monument yards, dairies (63, 64, 65, 66), furniture manufacturing plants (67), glass works (68, 69), hat factories; hospitals (70), laundries and dry cleaning plants (71, 72); lumber industry, municipal and government divisions (73), office and other buildings (74, 75, 76); paper mills (77 78), plastics (79) pottery and china works (80), power and light plants (81), printing and newspaper plants (82), public utilities, sewage plants, tanneries textile plants (83), water works and well drilling (84)

Industrial Plant Maintenance (85, 86, 87, 88, 89, 90)

Industries and other users of compressed air classified in this article apply this power to the particular work for which it is best suited in their individual field However, practically all compressed air users in industry have common problems in maintaining buildings and machinery General applications for compressed air in plant maintenance are the following

Cleaning by the positive pressure of air jets air tools, such as paving breakers, is used to repair concrete floors, opening masonry walls for various service lines and similar work Smaller air hammers are used for caulking and chipping Plants with well-placed air outlets use air-operated drills screw drivers and wrenches for other maintenance work Portable paint spraying outfits enable crews to keep ahead of this important maintenance job Sprinkler systems, especially in unheated portions of a plant are controlled by air pressure which prevents water from entering the pipes until heat breaks the seal and releases the pressure Cleaning of building floors, remote ceiling areas and overhead pipes progresses faster with the aid of air jets Boiler tubes are quickly and thoroughly cleaned with air pressure to remove the soot

The applications mentioned in this article are by no means a complete list of the many modern industrial uses for compressed air In every industry using this versatile power, there are companies which have developed their own ingenious devices or processes employing compressed air for production economies or improvements There are many general uses which have not been mentioned here However, the unmentioned applications, general or unique, usually incorporate one or a combination of the operating principles described

Illustrations for this chapter were obtained through the courtesy of the Compressed Air and Gas Institute, Chicago Pneumatic Tool Co, Independent Pneumatic Tool Co., and Ingersoll-Rand Co.

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CHAPTER VIII

ELECTRICAL INDUSTRY

by FRANK BENEDICT

The tremendous industrial development that took place during World War II was a direct result of the proper placement of productive power behind the industrial worker. This power took three main forms: diesel and gas power, steam power, and electric power. Of the three, the application of electric power for manufacturing has been general. The development and use of electric power in the United States has been continuous since the commercial introduction of the direct-current system in 1879 and the alternating-current system in 1886.

The installed productive power per worker has shown progressive increase, with 0.106 hp in 1899, 0.73 hp in 1909, 1.86 hp in 1919, 4.04 hp in 1929, 5.74 hp in 1939, and approximately 6.25 hp in 1946. It is estimated that the productive power per industrial worker will increase to at least 7.5 hp by 1950. The large increase in the number of industrial workers since 1939, coupled with the increase in horsepower per worker, has made it impossible for the electrical equipment manufacturers to keep pace with the industrial demands for power utilization equipment. The pressure for utilization equipment has been so great that few completely new items have been developed. There have been, however, many advancements in apparatus and equipment, some of which have resulted directly from war experience.

Fabrication—(1)

One of the most dominant factors in post-war designs is the method or process of *fabrication*. It would have been impossible to achieve the tremendous production of guns, tanks, and ships without recourse to welding in the fabrication process. The process of *materials joining* was intensively studied, and out of it came completely satisfactory methods for resistance welding and arc welding most of the common metals including aluminum, magnesium, and a great many of their alloys. Second in importance to welding in the fabrication process was the problem of riveting. Flush riveting in aircraft manufacture was developed to an exact science, and millions of man hours were saved in its extensive use. The possibilities of the explosive rivet have not yet been completely explored for possible industrial use, but it seems certain that this method has great possibilities in the light metal fabricating fields. Dozens of new types of shakeproof fasteners were developed and found extensive use in nearly every fabricating field. Many of these fabricating processes are applicable to the electrical manufacturing field and are being applied as rapidly as they can be proved satisfactory for use.

Lighter Weight

Designing for weight reduction was initially most active in the aircraft field. However, as weight reductions were achieved, with marked improvement in the products, industrial designers studied every detail of their designs to remove excess weight. While this resulted in a tremendous saving of critical materials, the effect to the user was in easier handling, less floor space, better appearance, and usually improved operation.

Substitute Materials (2, 3)

The importance of the weight reduction program was influenced to a marked degree by the trend to higher operating speeds of driven equipment to obtain increased production from a given machine or process. Rotating machine designs were most carefully reviewed to obtain factors of safety commensurate with the requirements of the applications. In many cases, the substitution of materials was the compelling factor in a specific redesign, but more often than not, the substitute material turned out to be as good as or better than the original material. Many of the important design changes during the war were a direct result of material substitution.

Materials (4-11)

A high percentage of the new materials developed during the war period was for a specific product or application. Now, as the characteristics of these new materials are made available to designers and manufacturers alike and their design limits are determined, new and improved designs will result. The new material field includes such materials as metal alloys, plastics, insulation, glass, ceramics, pulp and paper products, textiles, and many others. The electrical industry is vitally interested in these materials, and future designs will reflect their use.

High Capacity—Short Life

Many military devices were intentionally designed to give high capacity but short life. Such military expediency can be justified during a war period, but the life of industrial designs is measured in years, and only those design refinements that do not appreciably reduce the normal expected life of the design can be considered of value. Interpretation of these designs requires a great deal of engineering study, and it will be some years before the essential elements of these designs can be translated into satisfactory industrial practice.

Compactness—Unit Construction

The war expansion programs of many factories called for more production from the same working space This required very careful co-ordination of the driving and driven equipment to attain maximum utility of floor area and resulted in the development of more compact designs to meet the restricted space requirements Where more than one function was performed in an area, unit equipments incorporating all of the functions in one enclosure were developed Unit designs were very popular during the war and are currently being extended into new fields

Standardization

The war production program called also for the unprecedented expansion of existing plants and the building of thousands of new ones Each plant expansion as well as each new plant presented an overall electrical power problem that had to be met and solved before production could begin The standardization of electrical manufacturers' types, sizes, voltage and current ratings, horsepowers, frequencies, interrupting ratings, duty cycles, etc, was very helpful in reducing the number of special equipments that had to be manufactured to meet the desires of customers One of the manufacturers' problems was the education of engineers and plant designers in the selection of equipment that would be essentially standard and that would eliminate special engineering. It has been estimated that 20 million man hours of engineering time were saved by specifying standard, rather than special, apparatus As new industrial areas are developed, standardization takes on an added importance since the benefits of standardization include shorter deliveries on standard apparatus, lower equipment cost, lower installation cost, interchangeability of similar types of apparatus, simplified stocking of spare units, quicker repairs through standardization of parts, and simplified operator training

The Industrial Outlook

The future markets for electrical power utilization equipment will be open to many, all of whom will benefit from the unprecedented industrial progress accelerated by World War II It is generally agreed that the new designs and spectacular improvements are the instrumentalities used to gain entrance to, or maintain position in, lucrative commercial fields, and the electrical designers are already deep in the problem of translating war theory and design into realities that will improve electrical equipment

Industry in general finds itself enmeshed in the spiral of increasing labor and material costs In order to keep the price of its product or service to a minimum and at the same time realize a fair profit, each industry is energetically studying ways and means of reducing the cost of its product or service and at the same time is giving such design time as can be spared to the design of new products. The problem of cost reduction is being approached from three angles:

1. Increasing production with present or additional equipment;
2. Decreasing manufacturing cost by making cost analyses on all operations and applying rigid process controls to reduce costs; and
3. Improving the product to give it a definite market advantage at the present, or even increased, price

All three of these approaches involve the proper application of productive power equipment and may also involve all phases of the utilization of electrical energy.

Developments of interest to industrial power users are outlined in the following pages and may reveal opportunities for further industrial progress, since one or more of these items are factors in an economic study of any process that utilizes electrical energy in the manufacture of a product

Substations (12-54)

Both substation construction and equipment have undergone radical changes in the past five years The single-package idea for industrial power substations is experiencing a wide and sweeping acceptance A transformer and switchgear unit built as one piece brings to engineers and plant designers the greater flexibility and, in some cases, even actual portability that is so distinctly a present-day trend

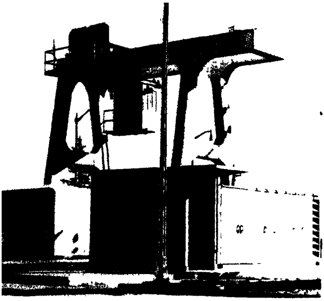
This trend to a large extent is based on conspicuous engineering improvements The functions of transformation, regulation, protection, circuit interruption, control, and metering of electric power heretofore performed by separate pieces of apparatus in an open structural-type substation have been combined into a single, completely enclosed, factory assembled unit. This type of equipment offers a neatly tailored appearance coupled with portability It has further advantages of compact assembly which results in a saving of space, economy and ease of installation, low operating and maintenance cost, fewer operating hazards, and complete co-ordination of all parts Single circuit unit substations are available in sizes ranging from 750 to 5000 kva, with high voltages from 12 to 132 kv and low voltages from 2 3 to 15 kv

For two or more feeders, a unit-substation throat-connected transformer and switchgear unit has been developed The size of a substation of this type is limited only by the breaker capacity, but sizes as large as 50,000 kva have been considered A high proportion of the applications lie between 1000 and 5000 kva and are manufactured for any practical combination of high- or low-voltage circuits

Recently the Duplex two-circuit substation has evoked considerable interest This installation consists of two substations connected on the secondary side by a tie breaker which closes when secondary voltage is lost by either unit, thus assuring a high degree of reliability and provision for an alternate power supply in case of a unit failure Present ratings are listed up to 20,000 kva per unit with practical limits set by the breaker size.

Where single-unit packaged-power substations are operated, demands for emergency service can be met by high-capacity trailer-mounted substations, which add mobility and flexibility to the features usually associated with conventional unit substations. Such equipment has been developed for primary voltages up to 69 kv, and its capacity is limited only by the maximum allowable trailer dimensions.

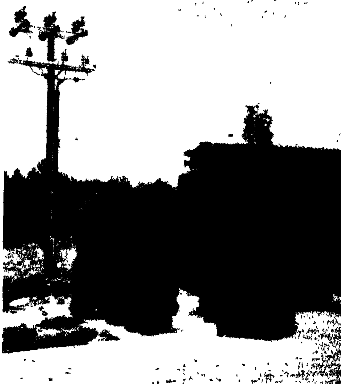
Transformers have been greatly improved in the last



Outdoor installation of vertical pump-motors with switchgear feature design of this modern pumping station.

five years by numerous material and structural developments. Physical sizes and electrical losses have been reduced through the development and use of grain oriented, high silicon, magnetic steels. Tank construction has been improved to the point where vacuum treating and filling the transformer under vacuum in its own tank are entirely possible. Such operations insure complete drying and thorough oil impregnation. All-welded form-fit tanks are increasing in popularity as they reduce the amount of oil required for a given design. Such tanks also provide tighter construction through the elimination of gasketing and bolting at the tank cover. Many power transformers are now provided with automatically controlled, inert gas atmospheres above the oil to prevent oil sludging and to reduce the effects of internal explosions. The sealed tank construction, with dead air space above the oil, has also been popular. New pump motors, operating directly in oil, have given added impetus to forced oil cooling and have resulted in smaller and more efficient units. Insulation design has been thoroughly reworked to incorporate the results of extensive laboratory experiments. For instance, it was found that insulating barriers were weak in creepage to impulse voltages as compared to 60-cycle voltages. On the other hand, it was found that insulating barriers have high-impulse puncture strength. As a result of these discoveries, transformers were designed to eliminate creepage surfaces so far as possible and to substitute for them insulation structures built in such a way that a failure could occur only by puncturing the solid insulating material. By this scientific application of insulation, the total amount of insulation in the transformers was reduced and the impulse strength greatly increased.

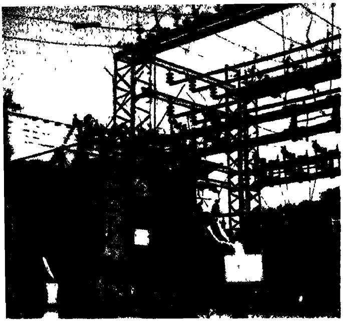
Lightning protection of unit substations is normally incorporated as part of the co-ordinated unit. The general problem of lightning protection of the industrial plant however may involve protecting the buildings against direct strokes, protecting the plant electrical circuits against direct hits, protecting the electrical machinery and apparatus against surges, and protecting the power source (conventional substation) against both direct hits and surges. Ground wires installed above



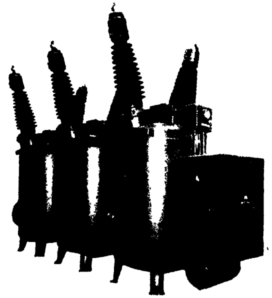
Single-circuit unit substation incorporates functions of transformer, regulator, circuit interrupter and meter.

Multiple-circuit unit substation utilizes air circuit breaker switchgear, packaged unit cuts installation costs.

Package substations up to 45,000 kva constitute a major advance toward standardizing electrical equipment.



Portable substation is readily tied in to substitute for existing facilities during emergencies or repairs.



High-voltage oil blast circuit breaker has sealed bushings, multi-break interrupter and is pneumatically operated.

Switchgear distributes 60-cycle power at 6600 volts to various circuits in this newly modernized steel mill.

exposed power lines have been effective in reducing direct hits to the lines. Properly installed shielding or installation of lightning rods has reduced the magnitude of induced surges on plant wiring resulting from direct or near direct hits. The application of valve type arresters alone or in combination with wave sloping capacitors has reduced plant equipment failures due to surges. Both valve and De-ion tube type arresters have been applied in substation protection up to 15 kv. Above 15 kv, valve arresters are considered to be superior.

In the past few years, considerable improvement has been made in valve arrester block capacity. Line-type arresters are now able to handle 65,000-ampere surges of short duration, while station-type arresters will handle 100-000-ampere surges of comparable duration.

De-ion tube arresters for use on circuits up to 15 kv have also been improved through lowering the impulse discharge voltage required for breakdown. The Westinghouse type A tube is not limited in its application by system fault currents since its action is current limiting. Those types that are not current limiting must be carefully applied to systems having limited fault current capacity.

Power fuses have been extended to cover new fields of application. An outdoor fuse has been developed for applications on systems up to one million kva at 138 kv. The fuse is designed to be used principally on transformer primaries which are tapped from high capacity systems at isolated substations. To provide positive disconnecting, the fuse swings open after operation.

The current-limiting fuse has been extended in rating to cover motor-starting service and application to small auxiliaries connected to high-power systems. The fuse is characterized by its high interrupting ability and rapid limitation of fault current without voltage surges. Ratings include 2.5, 5, 7.5, 15, and 23 kv. The 5 kv fuse has a nominal rating of 200 amperes with an interrupting rating of 60,000 amperes r.m.s. Ratings beyond 200 amperes have not yet been developed.

Disconnect switches have been completely re-designed to provide easier operation and positive action, particularly under icing conditions. The newest switch has only three moving parts, and the junction of these moving elements occurs within an enclosed housing. The blade is counterbalanced with a spring and provides improved ease of operation.

The load break disconnect switch was extensively used during the war for both indoor and outdoor service. NEMA ratings are 5 kv, 400 amperes; 7.5 kv, 200 amperes; and 15 kv, 100 amperes. These disconnect switches may be combined with power fuses to obtain high, short circuit interrupting capacity.

Switchgear (55-60)

Drawout low-voltage metal-enclosed switchgear is now being used as a general practice in industrial plants. Five classes of low-voltage breakers are available with interrupting ratings of 15,000, 25,000, 50,000, 75,000, and 100,000 amperes with current ratings up to 6,000 amperes alternating current.

The low-voltage metal-enclosed switchgear assemblies are constructed of individual units, any member of which may be bolted together to form a complete structure and to meet the most economical bus arrangement.

Each front breaker compartment is completely isolated, and the number of compartments in each unit is determined by the size of the breaker (manual or electric) and the interrupting rating The metal enclosure for buses and cables at the rear of the structure consists of universal frames which are available in 6-inch steps and which provide flexibility in locating the buses and in mounting accessories Metal barriers are provided between main bus sections

Low-voltage breakers are often applied on the cascade principle, where only those breakers nearest to the source of power require full interrupting ratings while the breakers in succeeding steps further from the source may have lower interrupting ratings Such applications often represent a great saving in initial cost, but it must be realized though that this saving is not obtained without some risk and sacrifice in overall performance Mechanical, definite time-delay devices applied on the cascade principle will have positive selectivity up to 80 percent of the interrupting rating of the next lower breaker in the cascade, while breakers applied with full interrupting capacity will have complete selectivity comparable to that which now is obtainable only with relays

For medium-capacity applications requiring interrupting capacities of 50,000 to 500,000 kva at 2 3 to 15 kv, the trend is toward metalclad switchgear utilizing oil-less circuit breakers of the magnetic blowout type Although the development began almost 15 years ago, it is only in the last few years that it has started to crowd out the oil breaker

The standard base unit is designed for single-bus operation with the bus, circuit breaker, and current transformer and cable terminals in separate compartments with grounded steel barriers between The bus compartment is arranged to permit direct connections to the disconnecting switch contacts for maximum reliability.

Other typical bus arrangements such as the double bus, double breaker, or transfer bus are readily obtained, using the standard single-bus base unit, by mounting two back-to-back for the first case or by adding a transfer bus and disconnecting switch compartment either as a superstructure over the base unit or as a separate structure Auxiliary compartments are used to house accessory equipment such as operating or potential transformers, surge protective equipment, and totalizing transformers to form a complete metalclad switching structure Any of the standard indoor arrangements can be used in outdoor stations by adding weatherproofing details.

Electrification in the petroleum and chemical industries has been marked by a gradual but inevitable increase in the specialized forms of apparatus developed to meet conditions of atmospheric corrosion and explosion hazard for which general purpose lines are inadequate. Explosion-resisting motors and control have been developed to meet the most exacting application conditions. Switchgear, due to its size and complexity, is very difficult to make explosion resisting; however, switchgear in which all current breaking contacts are oil immersed has been developed. The gear is of the vertical lift type with oil breakers, and extensive measures are taken to protect hazardous points

A major improvement in metalclad switchgear came in the provision of means for making the large assembled housings rust resisting This process, known as bonderizing, has been extensively used by automobile makers to protect car bodies, but only recently has it been applied to protect assembled switchgear enclosures of large size and thick gauge In addition to the protection provided, a better paint base is assured which gives better appearing, longer lasting finishes

The general trend in switchgear equipment emphasizes ruggedness of structure, accessibility for ease of maintenance, standard parts for simplification of stocking parts and for ease of replacement, higher operating safety, and design standardization to decrease unit cost to both the manufacturer and the user Instrumentation trends are towards flush mounted instruments, meters, and relays, smaller, long-scale instruments with better illumination for eye ease in reading, improved, positive-action test switches, improved indicating light construction for positive color indication, ease in bulb replacement, and rugged, positive action instrument switches

Plant Distribution Systems (61-120)

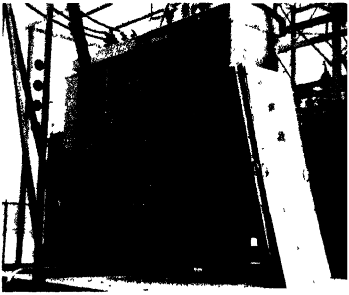
The large number of new plants built during the war provided engineers with the opportunity of studying and applying various types of plant distribution systems Of the systems studied, the radial and network types were the most favored, and apparatus to further their applications was extensively developed

The simple radial system consists of a power source, usually a plant substation which supplies power to single or multiple radial feeders from a main distribution bus For small plants requiring a single power source with less than 1000 kv capacity and less than 8 watts per square foot of floor space, the radial system is cheaper to install and maintain but has limitations which must be economically evaluated The factors of most importance are.

1 Production can be completely interrupted by primary substation failure
2 Failure in any main distribution bus interrupts all service
3 Failure in any secondary feeder interrupts service on an entire circuit.
4 Voltage regulation is not uniform because of the unavailable voltage drop in long, low voltage, feeder lines Voltage at load centers removed from the substation cannot be maintained because of long lines.
5 Any major expansion of the system involves—(a) increased substation capacity, and (b) new main switchgear units for the main distribution bus and new distribution centers where they are used.

The alternating-current secondary network system has been used for many years to better distribute power in the business areas of cities and in large commercial buildings, and the system has now been adopted for use in industrial plants The best known advantage of

Air cooled dry type transformer, adjacent to switchgear, represents the safest type of unit for indoor operation.


Outdoor installation of a 1080 kva capacitor unit; it is automatically switched in response to line voltage.

the alternating-current secondary network system is continuity of service No single fault anywhere on the system will interrupt service to more than a small part of the system load Most faults will be automatically cleared without interrupting service to any load

The outstanding advantage which the network system offers is its flexibility, in most industrial applications, to meet changing and growing load conditions at a minimum cost and with a minimum of interference with the normal operation of the plant In addition to flexibility and service reliability, its also provides exceptionally good voltage regulation, and its high efficiency reduces the cost of losses

Physically the secondary network system differs from the simple radial system in three ways, all of which account for its outstanding advantages First, a network protector is connected in the secondary leads of each network transformer in place of the secondary breaker The purpose of the network protector is to protect the secondary loop and leads fed from its against transformer and primary feeder faults by disconnecting the defective feeder transformer when the back-feed occurs Second, the secondaries of all transformers are connected together by a ring bus or secondary loop, from which the loads are fed over short radial circuits, which results in a saving in transformer capacity, a saving in secondary load circuit copper and conduit, lower system losses, and improved voltage regulation. Third, the high-voltage feed consists of two or more primary feeders having sufficient capacity so that the entire plant load can be carried without overloading when any one primary feeder is out of service.

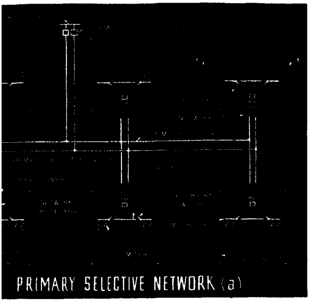
The industrial plant network system may take a number of forms The most commonly used is the primary selective network with loads fed from the secondary loop at transformer feed-in points only A simple variation of this system, in which some loads are fed from the secondary loop between transformer points, has been satisfactory While the network normally uses two primary feeders, three or more may be used. Reliability is improved, but in any case the additional expense must be justified.

Both the simple and the primary selective network systems may take a form known as the spot network system In this system two transformers feed through network protectors to a load bus The simple and spot network systems have been combined in some cases where specific types of load are present

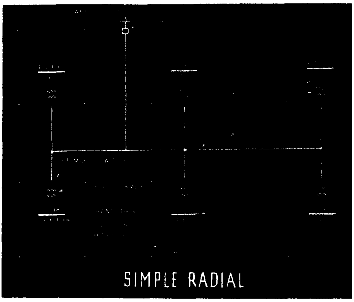
Network Units

The swing to network applications has been a result of equipment development In the first place, limiters had to be developed and tested before 460-volt networks were practical The limiter is a device for disconnecting a faulted secondary loop cable from a distribution system and for protecting the unfaulted portions of that cable against serious thermal damage by means of a heavy copper fuse which is operated by passing current through it The fusible member is completely enclosed so that there is no visible flame or smoke when it operates within its rating Limiters for industrial plant networks are suitable for use on circuits of 600 volts and below at 60 cycles and have an interrupting rating of 50,000 amperes Limiters are designed to be used with specific cable sizes, the largest being 600 MCM for use with type RH or type V cable The minimum fusing current of a limiter is about 3 to 3½ times that for the 1940 National Electric Code rating of the cable with which it is designed to be used This value of fusing current is necessary to insure positive selectivity among the limiters in the secondary loop In addition to preventing unnecessary limiter blowings, the high fusing current value of the limiters also has the advantage of keeping the normal temperature of the limiter terminals relatively low so that the associated cable can be used at full rating

To meet the necessary requirements, new and safer transformers had to be designed for industrial network use. Air cooled, fire and explosion proof, and noninflammable liquid transformers have now made it possible to locate the network transformers adjacent to the loads without the expense of constructing expensive vaults. Air-cooled transformers are smaller and lighter than the corresponding liquid-filled transformers. Case



PRIMARY SELECTIVE NETWORK (a)



SIMPLE RADIAL

and coils are enclosed in lightweight, but strong, sheet steel cases with grilled openings at the top and bottom for circulating cooling air through the transformer Combustible material is practically eliminated with porcelain, asbestos, mica, and glass comprising the major insulation These air-cooled transformers, enclosed in their metal cases, are by far the safest transformers ever developed for indoor operation

Non-inflammable liquid-filled network transformers have been used in subway and outdoor service for many years, and many improvements have been made in the switching, transformer construction, and network protectors over this period of time These sealed transformers are capable of being completely immersed for an indefinite period

In many plants the major electrical loads are alternating-current induction motors which have inherently low power factors at start in the order of 30 to 40 per cent, with full load power factors seldom more than 85 per cent If the plant is overmotored, with many motors running at light loads, plant power factors may run as low as 65 to 70 per cent Where synchronous motors cannot be applied in the plant for power factor control, power capacitors are generally installed to provide the necessary reactive kva to raise the plant power factor to 90 per cent or more. Where the plant power factor is variable, automatic capacitor switching equipment has been extensively developed and applied Power capacitors have also been used for starting large motors on long lines, which could not have been done otherwise without a prohibitive increase in the cost of the lines.

Capacitors for power factor correction may be installed either outdoors or indoors The new finishes used on outdoor capacitors permit permanent installation outdoors. This new finish is obtained by first sandblasting the capacitor case to remove all scale and to produce an irregular surface and then by spraying it with vaporized metallic zinc to produce a coating about 0.005 to 0.006 inch thick. This coating is permanent and highly resistant to corrosion.

Power Centers

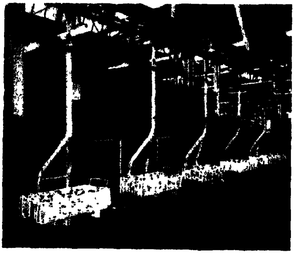
The power center is a completely co ordinated, indoor unit substation consisting of (a) a high-voltage section rated 15 kv or less (b) a transformer section rated 2000 kva or less and (c) a low-voltage section rated 6000 volts or less The high-voltage section usually includes a line entrance unit comprised of cable entrance equipment and a switch unit comprised of a primary feeder disconnect switch, a primary feeder loop sectionalizing switch, and primary feeder selector switch power fuses The transformer section may use either air, oil-, or Inerteen-type transformers, depending on the application For instance, industrial applications utilize air-cooled transformers almost exclusively The low-voltage section is composed of feeder bus and breaker arrangements to supply power to the desired feeders This arrangement may include built-in panelboards and/or breakers Power center developments include subway types, floor-mounted types, roof truss-mounted types, and outdoor roof-mounted types

Power centers are generally made applicable to network systems by the addition of a fourth section composed of a network protector unit and a load bus unit As these power centers may be placed within a plant at or near the center of the load area, large amounts of secondary copper are saved and voltage regulation is improved. The air-insulated transformer type has decided advantages over oil or Inerteen transformers for several reasons—no liquids are required, no catch basins or drains are needed, and fire, explosion, and toxic gas hazards are eliminated Then too the lighter weight and increased safety permit overhead installation, even directly above the work area, thereby saving valuable floor space Inspection and maintenance are also simplified.

Plant Distribution Transformers

Industrial plant auxiliary power at 110 and 220 volts is usually obtained from dry-type distribution transformers A review of progress during the war years in dry type distribution transformers shows constant improvement in performance and weight at a rate almost unparalleled The present 50 kva unit weighs less than

World's largest lightning arrester protects transmission lines; transformers deliver up to a half million volts.



Power centers are best located in the work load area; this saves secondary copper and improves voltage regulation.

Busway system distributes power to drive motors of a paper machine; high humidity requires special sealing of duct.

the 15 kva model of 1938 and is considerably smaller in occupied space. Through their use performance has been improved, weight has been reduced by the use of special, grain oriented, magnetic steel and specially developed class B insulation, and operation at higher temperatures has been possible The latest units have been standardized to a point where their mountings and connections are interchangeable among all manufacturers

Cables and Wiring (121-135)

Industrial plants utilizing the newest types of power distribution equipment require cables up to 15 kv rating Varnished-cambric and paper-insulated cables were extensively used during the war Rubber cables practically disappeared at that time, but have now returned to the market with supply and demand about in balance Conduit was very difficult to obtain during the war, and lead-covered and armored-cable types predominated

With the serious shortage of rubber and rubber compounds, the development of synthetic insulation was accelerated Development took two main approaches, (a) thermoplastic materials and (b) thermosetting materials Thermoplastic insulation is usually a compound of synthetic resin (usually polyvinyl chloride or its co-polymer) and other materials The insulation is compounded, milled, and then extruded on the conductor Applying in calendered tape form with or without heat sealing is less common than extruding The general characteristics of this type of insulation are its high dielectric loss, excellent moisture, ozone, chemical, and oil resistance, flame resistance, thinner insulation giving a smaller space factor, suitability for use without braids or other covering, and variety of colors This insulation is adaptable for uses such as building wire, machine tool wiring, and radio-circuit and hook-up wiring.

Thermosetting insulation is usually composed of synthetic rubber, predominantly Buna S, with limited amounts of butyl rubber and other materials It is usually compounded, milled, extruded, and then vulcanized, although some processors apply the extruded material as flat stock in a strip-insulating process and then vulcanize it. General characteristics include a lower dielectric loss than thermosetting insulation, low resistance to sunlight and ozone in certain grades, marked superiority to natural rubber in oil, moisture, and chemical resistance, but poorer than thermoplastic insulation in this respect; and improved flexibility over thermoplastic insulation at low temperatures. A very large number of grades of this material have been developed, and the industry has established several grades for general purpose wiring --(a) Code Grade–residential and lower classes of commercial and industrial wiring (5000 volts maximum at 60 deg. C), (b) Heat Resistant Grade–a better grade for commercial and industrial wiring which has longer life (8000 volts maximum at 75 deg. C.), (c) Moisture-Resistant Grade–for moist locations (5000 volts maximum at 60 deg C.); (d) Performance Code–designed for long life and has excellent electrical values and physical properties (800 volts maximum at 75 deg. C. and 28,000 volts maximum at 70 deg. C.); (e) Latex-Insulated Grade–a thin wall of 90 per cent unmilled grainless rubber which is obtained by a dip process (No. 14 to 6 Awg incl.) and which saves conduit space and has high dielectric strength; and (f) Special Compounds—include wire for special services such as submarines, networks, communications, railway signals, ships, etc.

High-pressure oil and gas types of cables have not been used in industrial work except in very special cases These types are under active development for high voltages up to 230 kv at oil and gas pressures up to 200 lbs per sq. in

Busways

With the war scarcity of copper, steel, and insulating materials, busways of various types were developed for general plant distribution systems A busway system is an installation of metal-enclosed bus bars running over head, supported by hangers attached to columns or to the ceiling The metal busway enclosure is usually steel and in some cases is perforated to give better ventilation The busway is manufactured usually in 10-foot sections, and a large number of types of elbows, tees, cross overs, cable tap boxes, expansion joints, etc, have been developed for making a complete installation Development has been most active on five general types

1. Plug-in and feeder busway (250-1500 amperes)
2. Conventional feeder busway (2000-3000 amperes)
3. Weatherproof conventional busway (2000-3000 amperes)
4. Interlaced low-impedance feeder busway (1000-4000 amperes)
5. Weatherpoof interlaced feeder busway (1000-4000 amperes)

Plug-in busways were developed for industrial plant applications where equipment saturation required flexibility so that re-arrangement could be quickly accomplished Receptacles or openings are provided at about one-foot intervals along each side of the busway to accommodate plug in breakers, switches, etc This type of busway is built in standard ratings from 250 to 1500 amperes and 600 volts for two wire, three wire, or three-phase four-wire service

Feeder busway up to 1500 amperes is of the same construction as plug-in busway. Above 1500 amperes, feeder busway has been developed in conventional and low-impedance interlaced types These designs do not have plug-in features Both types have been developed with weatherproof construction for outdoor service For long feeder runs, low-impedance interlaced busways give improved voltage regulation over standard arrangements.

Trolley types of busways were developed for supplying moving loads. The bottom of the steel housing serves as a track on which the wheels of the trolley roll. The trolley itself is sufficiently heavy to support the weight of most portable tools involved Electric connection between the trolley and the busway is made by means of rollers or brushes which make contact with the busbars which are rigidly supported in the busway.

Busways are always structurally designed to meet the specific requirements of short-circuit stresses of the electrical distribution systems in which they are to be used. Most commercial busways will withstand short-circuit currents of 25,000 amperes and some over 50,000 amperes It is seldom necessary to design for short-circuit currents in excess of 50,000 amperes as the impedance of the busway circuit to the short is usually high enough to limit the current to this value Busways are normally supplied with low-voltage switchgear or power centers located within the plant They may however be used wholly outdoors with outdoor power centers and unit substations

Control Centers

With the heavy concentration of power and machines in manufacturing plants, motor controls were installed by the thousands Many of these controls for such items as pumps, compressors, fans, etc, did not require attendance, and the problem of starting-up such equipment from controls on each machine was a time-consuming job To meet the need of centralized control, the control center was developed so that the placement of a starter for a single machine, a group of machines, or an entire plant could be completely centralized

The power center makes control of motor drives safer and more efficient Steps are saved and all unnecessary motions eliminated The cost compares favorably with that of open framework structures and is well below the cost of made-to-order control centers Wiring troughs simplify wiring and eliminate the need of costly individual conduit runs Individual, self-supporting structures eliminate special foundations or supporting structures Centralizing the control saves valuable plant space and helps keep aisles clear for traffic.

The use of internal buses and wiring troughs gives maximum safety Each individual unit is completely baffled from other units in structure, and each starter is individually removable from the front of the structure Line-starters are interchangeable by making starter unit dimensions multiples of the smallest size Combination starter and circuit breaker units are provided with handle interlocks which prevent access to the starter compartment unless the breaker is opened.

Control centers may be arranged in various ways for mounting—two groups, back-to-back, "L" shape, front mounting or back-to-back, "U" shape, front mounting or back-to-back, and control aisles, front mounting or back-to-back Present designs include NEMA starter ratings up to and including size 4 at 220, 440, and 550 volts 3 phase This covers the squirrel-cage induction motor range from 1 to 100 hp and meets general industrial needs For large machines metalclad switchgear is normally applied.

Industrial Plant Power Generation and Conversion Equipment (139-194)

Very little new plant generating equipment was installed in the war period. Existing sources of power had to be utilized to the fullest extent before authorization for additional capacity could be secured However, those machines that were installed incorporated the latest developments in both generators and turbines Recent and current developments fall under one or more of the following categories—improvement of unit reliability, adaptation of turbines to improved thermal cycles, improvement of turbine efficiency itself, and greater concentration of power in a single unit. Most

60-cycle alternating-current turbine generators for industrial service are single-cylinder units, direct connected to 3600 rpm generators Direct-connected exciters are standard Twenty-five cycle generators and direct-current generators from 500 to 7500 kv are usually coupled to a high speed turbine by a double helical reduction gear

Turbines are built in various types including the straight condensing, non-condensing, automatic single extraction, automatic double extraction, mixed pressure, and low pressure as required by the application Where the primary purpose is generation of electrical energy the straight condensing turbine is a highly economical unit For applications requiring generation of electrical power and steam for heating or process, the automatic extraction is the simplest and most flexible unit Non-condensing turbines are desirable as reducing valves between boiler pressures and process steam pressures and are applied where process steam demands are equal to, or more than enough to, generate the electrical load For industries tending to have surplus steam in summer and a deficiency of low-pressure steam in winter, the mixed-pressure turibne has found wide application

Turbine developments include new and improved casing materials, new and more-efficient blading, improved governing systems, improved lubrication systems, new automatic extraction controls, new and improved steam piping, and many others Condensers have been increased in efficiency, and new tube materials have reduced tube failures under severe operating conditions

Generator developments include flexibly mounted stators, hydrogren cooling at increased pressures, longitudinal air or hydrogen coolers, new rotor and stator cooling methods, improved insulating materials, corona treatment on windings, improved retainer ring construction, low loss silicon steel punchings, high strength alloy steel forgings, and closed multiple-circuit recirculating ventilating systems

A 5000 kw standard power plant, developed during the war to provide electrical power in devastated areas abroad, has recently been announced The plant contains a boiler, turbine generator, steam condenser, pumps, piping, electrical equipment, wiring, and other essentials This completely developed package unit relieves the operating company from co-ordinating the complicated unmatched apparatus so often found in generating stations in which equipment has been purchased from numerous suppliers. The turbine is supplied from a 75,000 lbs/hour boiler at a pressure of 460 lbs. per sq. in at 750 deg F. The generator is 3600 rpm, direct connected, and is capable of developing its maximum rating of 6250 kw continuously with a maximum condenser cooling water temperature of 89 4 deg. F The electrical system of the plant is laid out along conventional lines with generators at 13.8 kv or below as desired. Reliability is assured by the use of heavy-duty switchgear specifically designed for power plant use Safety features are integrated into the plant throughout, and accessibility for maintenance is specifically provided.

For the larger machines, say 10,000 kw and up, temperature and pressures are reaching practical limits with present materials The maximum pressure to date has been 2300 lbs and the maximum temperature 1059 deg F Below 10,000 kw, industrial turbines range in pressure from 26 lbs to 1500 lbs with temperatures of 950 deg F and lower

Many plants require direct current for part or all of their operations Turbine-driven direct-current generators are usual where steam is available, and synchronous motor generator sets or ignitron rectifiers are used where power must be obtained from alternating-current sources Ignitron rectifiers of the sealed and pumped type have practically superseded motor-generator sets for many applications

For small blocks of power, where high overload conditions do not exist, the sealed ignitron rectifier has been widely applied in industrial work Unit substation construction has been preferred by most users as such construction provides alternating-current switchgear, an ignitron rectifier power transformer, an ignitron rectifier, and a set of direct-current switchgear in a packaged unit Alternating-current switchgear is of metal-enclosed construction with removable type breakers For alternating-current voltages up to 5000 volts, air breakers are standard, and above 5000 volts oil breakers are standard The main rectifier power supply transformer may be oil filled, self cooled, non-inflammable, liquid filled, self cooled, or air cooled, dry type as required by the application Dry-type transformers cannot be supplied above 750 kw 15,000 volts alternating current for general applications or above 5000 volts alternating current for coal mines Transformers are equipped with all standard accessories associated with that particular type of transformer

The ignitron rectifier is completely enclosed in a metal cubicle The assembly consists of the proper number of ignitrons with their attendant accessories All apparatus in the cubicle is completely wired at the factory Ignitron rectifier tubes are arranged for water cooling from plant sources or by recirculation and cooling by water to air heat exchangers where plant water supply is not available Direct-current switchgear consists of single- or double-pole circuit breakers, depending on the grounding of one of the polarities. Breakers are usually of the metal-enclosed drawout design Above 500 kw at 600 volts, the direct-current breakers are of the heavy duty, semi-high-speed type in open construction, fixed mounting Standard ratings have been developed and include 125 volts direct current, 40 to 250 kw, 250 volts direct current, 75 to 500 kw; 275 volts direct current (mining service), 75 kw to 500 kw; and 600 volts direct current, 100 kw to 1000 kw.

Where large blocks of direct-current power are required or where overload conditions may be very severe, pumped ignitron rectifiers have been extensively applied. About 90 per cent of the aluminum industry utilizes pumped ignitron rectifiers in their electrolyte processes, and other industries such as magnesium, electroplating, steel mills, etc., have found ignitron rectifiers efficient and economical power conversion units.

Sustained power is a vital factor in all phases of electrochemical processing. Standard heavy-duty switchgear helps in this important job by reducing maintenance and inspection time For electrochemical applications, two pumped ignitron assemblies, each rated 5000 amperes, are supplied from each rectifier transformer High-speed 6 pole anode circuit breakers give fast, selective clearing for faults on any phase while remaining phases remain in operation Standard metalclad switchgear controls the primary circuits and provides five important advantages (a) improved service continuity, (b) full accessibility, (c) complete operating safety, (d) advanced, standardized manufacturing design, and (e) quick breaker inspection Complete control of the entire ignitron installation is centered in a duplex switchboard which handles the duplicate functions involved in starting each rectifier unit Control switches and indicating instruments are front panel mounted, protective relays and recording meters being placed in the rear A metal-enclosed auxiliary control cubicle contains the vacuum and cooling system control and excitation circuit equipment The installation is completed with heavy duty, single pole, semi high-speed cathode air circuit breakers

For general industrial applications, the same general type of pumped ignitron equipment is used with the ratings dependent upon the rectifier size For railway service, automatic control has found wide acceptance The starting functions performed automatically are closing the alternating-current breaker to energize the transformers checking vacuum and cooling systems, energizing excitation equipment, and closing direct-current breakers to deliver power to trolley feeders The rapid, continuous protection system operates in two groups– the first shuts down the rectifier until it is restarted by the operator, the other shuts down the equipment during an emergency only The types of faults considered sufficiently serious to require personal attention of the operator include repeated alternating-current overcurrents (equipment locks out after three automatic reclosures), alternating-current grounds, recurring arc backs, and over-temperature in tubes or mercury vapor vacuum pump Other temporary emergencies which permit automatic resumption of service include direct-current over-current, loss of alternating-current line voltage, excessive pressure in ignitron tubes, and over-temperature of the rectifier transformer When a feeder breaker has been tripped, relays on the feeder circuits will automatically reclose the breaker after the fault is cleared

For mining service, a low height, portable unit has been developed wherein both pumped and sealed ignitron tubes units have been applied successfully Functioning is made fully automatic to improve reliability and decrease maintenance and operating costs.

Ignitron rectifiers are normally equipped with voltage regulators so that they may be paralleled with existing direct-current generators, provided the generators have a suitable regulation curve. The efficiency of ignitron rectifiers is normally higher than motor-generator sets over the whole load range For 250-volt direct-current operation, the ignitron unit efficiency is higher than that of a motor-generator set throughout the normal load range. It is higher than a synchronous converter up to 50 per cent load and lower beyond 50 per cent load For 600-volt operation, the ignitron unit efficiency is higher than that of a motor-generator set throughout the normal load range It is higher than the efficiency of a synchronous converter up to 100 per cent load and lower beyond 100 per cent load in the larger ratings For operation at above 600 volts, the efficiency is higher than that of other types of rotating conversion units throughout the normal load range Efficiency does not always govern the application, and economic studies should be made when both types of conversion are considered

Rectifiers for supplying direct current for merchant mill roll drives have been used in a recent application Phase control of the rectifier is used to start the mill motor as a variable voltage unit with the mill empty With the mill in normal operation, the motor load is carried by the rectifier operating at substantially full voltage Necessary are rectifiers are not designed for regenerative braking but it is not required on this type of mill

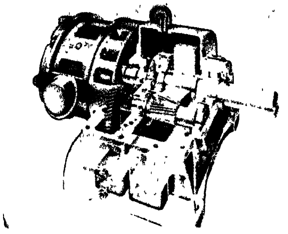
For small blocks of power for charging batteries electroplating, chemical processing, etc, copper oxide rectifiers have been applied extensively Such rectifiers may be air or liquid cooled and are rugged and reliable Selenium rectifiers are under active development and, because of their smaller physical size, may find extensive application in small, compact rectifier units

Mechanical Drive Turbines

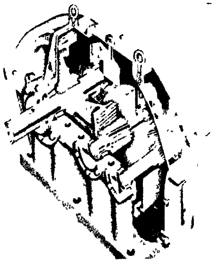
Turbines driving plant equipment directly have been widely applied to such equipment as fans, pumps, pulverizers, paper machines, line shafts, etc These turbines are usually single-stage with single governor valves or multi-stage with either single or multiple governor valves and are coupled through a reduction gear unit Gear units are either the self-contained coupled type or the close-coupled integral type in which the gear housing is supported from the turbine casing Gear ratios range from 2 1 to 14 1 Conservative tooth pressures, adequate lubrication, and extremely accurate hobbing insure quiet gear operation with long life Oil relay turbine governors provide output shaft speed ranges of 25 to 1 with constant speed at any load or any speed setting within this range

Gearmotors, Speed Reducers and Increasers (195-197)

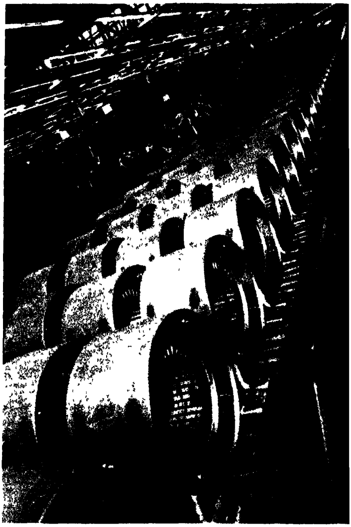
Approximately 80 per cent of all driven machines must operate at speeds other than that provided by the prime mover For low powers, 1 to 75 hp, gearmotors provide the simplest speed reduction devices available The most common types are single reduction, from 1 22 1 to 6 25 1, double reduction from 7 6 1 to 25 7·1, and double reduction, from 31 2 1 to 58 3 1 Gearing parts are designed and applied in accordance with the standards of the American Gear Manufacturers Association. Standard gearmotors are available with all regular auxiliaries common to standard motors, such as enclosures and special grades of insulation which may be required for specific applications They are readily equipped with motor-mounted-magnet brakes. Specially designed slide bases have been developed for adjustment



Up to 75 hp., gearmotors provide the simplest type of speed reduction.



Separate speed reducers such as this may be used with any type of prime mover.



Mass production of electric motors is playing a big part in meeting the tremendous demands of expanding industry.

of belt or chain tension where the drives are installed with such power take-off Motors may be of the open, totally enclosed, splash-proof, or explosion-resisting types and may operate on either alternating current or direct current

High-speed motors which have an inherent high efficiency and high power factor are direct connected to the gears Friction losses are minimized through the use of anti-fraction bearings, single helical gears, and a positive lubrication system. Quiet operation in the latest units has been obtained through a final gear-shaving process which produces long wearing, accurately formed mating surfaces.

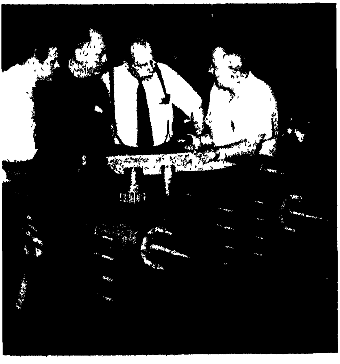
Speed reducers may be used with any type of prime mover (such as electric motors; steam turbines, gas, oil, or Diesel engines) to economically transmit the required power at the exact speed requirements of the driven machine. Both single- and double-reduction types have been developed Single-reduction reducers have standard ratios from 2 82.1 to 9.5:1 and capacities to transmit from 1 to 1380 hp, with thermal ratings from 34 to 600 hp. Double-reduction reducers have standard ratios of 11 8:1 to 70 5:1 and capacities to transmit from 1 to 520 hp, with thermal ratings from 9 to 360 hp.

Helical gears, cut by the hobbing process after heat treating, insure smooth transmission of power and quiet operation Anti-friction bearings provide for permanent alignment and minimum friction loss The efficiency of single-reduction reducers has gradually been raised to about 98 per cent, while double-reduction efficiencies have been raised to between 96 to 98 per cent

Speed increasers have been specifically designed to supply speed in excess of that which can be directly obtained with economy and safety from ordinary prime movers Speed increasers are applied for driving pumps, centrifugal compressors, and alternating-current and direct-current machines from slow-speed prime movers. In high speed service, the pinion shaft of the speed increaser units often turns at 6000 rpm or higher, with the pitch line velocity of the gears reaching as much as 12,000 feet per minute. When equipment is operated at these velocities, the problems of vibration, impact stress, sound level and proper lubrication become acute. To obtain high efficiency at the lowest possible sound level, specific features have undergone continuous study and refinement. Accurately hobbed and dynamically balanced gears; positive forced feed lubrication; special alloys; oversize machined bearings; oversize shafts to prevent distortion; and extra heavy gear cases for smooth quiet operation have been developed. As a result the efficiency of speed increasers has been increased to between 96 and 98 per cent.

Rotor for a 600 hp, 2300 volt, 3 phase, 60 cycle, 1185 rpm. electric motor is equipped with fans.

All-steel motors feature pre-lubricated bearings, improved magnetic circuit, die-cast rotors, better insulation.



Mine explosion hazards are reduced with this flat-type explosion-proof motor that develops 50 hp at 1750 rpm.

Motors (198-232)

The tremendous industrial expansion required integral horsepower motors of all types, such as alternating-current single phase, polyphase squirrel cage, polyphase, wound rotor, synchronous, and direct-current motors. Standard motor types provided a wide range of speeds, horsepowers, and enclosures to meet practically any service requirement. With emphasis placed on saving critical materials during the war, machines of most types were applied to take advantage of the inherent overload capacity normally incorporated in the machine. Operating experience, improved designs, new materials and techniques have resulted in the reduction of the physical size of many machines while maintaining all normal operating characteristics such as temperature rise and speed-torque relations.

Developments on single-phase motors have been chiefly confined to the split-phase, capacitor start, induction run types. The repulsion, start-induction run type motor has been widely used in the past, but it is more expensive to manufacture than the split-phase type as it requires a wound rotor and segmental commutator while the split-phase type utilizes the simpler die-cast rotor construction. News designs of split-phase motors are now being made with torques equivalent to the repulsion induction type. The split-phase type requires disconnection of the starting winding after the rotor reaches a pre-determined speed, and much development work has been done on disconnecting devices. Stationary switches, actuated by shaft-mounted centrifugal devices and by current relays operated by a reduction in stator current with speed, are most popular. For the same starting torque, the starting current inrush of the split-phase machine is higher than that of the repulsion machine, but design improvements are rapidly overcoming this disadvantage. The repulsion machine requires considerable maintenance of commutator and brushes, while the centrifugal switch or relay of the split-phase motor are relatively free of maintenance. Split-phase motors must be carefully applied on drives where the driven equipment may have high starting but low running friction due to design or temperature factors. Applications where dirt may foul the centrifugal switches on the split-phase type must also be guarded against. This same caution applies to commutators and brushes on repulsion induction motors.

Polyphase squirrel-cage motors have undergone many face liftings in the past 45 years, but few fundamental changes have been made. Improvements in electrical design have resulted in higher efficiency and higher power factor operation, with lower starting kva inrush demand, while mechanical refinements have added reliability and mechanical ruggedness. Die-cast rotors for induction motors are now standard with most manufacturers. Imperfections have been reduced to negligible amounts through the development of improved casting methods and new die casting alloys. Bearings are usually of the sleeve or ball type. Automotive practice has been reflected in the development of the thin-wall steel-backed babbitt sleeve bearing used by several manufacturers in the smaller integral horsepower motors. Sealed, pre-lubricated ball bearings have been used on textile motors for many years and have been very satisfactory. The application of this type of ball bearing is being extended to many new lines and bids fair to appreciably reduce bearing maintenance. A new all-steel induction motor features fabricated all-steel frame and brackets, pre-lubricated ball bearings, improved stator windings using synthetic enamel-covered wire and continuous wound coils to eliminate joints, die-cast rotor shrunk on the shaft, and 180-degree rotatable conduit box set in the recess between frame and foot The motor is fully one-third smaller and lighter than its predecessors with improved starting and pullout torque and with no sacrifice in overload capacity Its appearance has been bettered, its ability to withstand severe handling has been improved, and the need for maintenance has been markedly reduced

Wound rotor motors and synchronous motors have been bettered by the use of new types of insulation, by the redesign of electric and magnetic circuits, and by the use of fabrication methods in construction of mechanical details

Present features of direct-current motors include improved insulation, better commutators, improved brush-holders and brackets, improved field coil construction, re-worked magnetic designs to give better commutation, and improved ventilation methods permitting smaller machines Speed variation in a direct current machine is normally accomplished by varying the field strength, with a practical speed variation of 4 to 1 possible For wider ranges some additional feature, such as variable voltage with attendant changes in horsepower output, is required New four-pole direct-current motors that are essentially standard are providing twice the speed range—or about 8 to 1—with no change in rated output at any speed Essentially, this is accomplished by separate control of two of the four field coils Two adjacent poles are energized in the usual manner to supply a nearly constant magnetic flux The remaining two poles, by a special resistor, are varied in flux strength from maximum down to zero and finally reversed Thus, the combined flux can be changed from a value representing the sum of all the fields to the much smaller total of their differences Since the armature voltage does not change throughout this entire range, output remains essentially constant as the speed varies

For internal grinding, ultra high speed induction motors up to 120,000 rpm have been developed The rotors of these machines must be very accurately balanced to eliminate vibration The grinding head is usually mounted directly on the motor shaft with the rotor and stator integrated as a part of the machine tool. Such motors are usually operated at frequencies of 120 to 850 cycles to simplify the winding

With the many unusual applications of motors to war equipment, the study of insulations and insulating methods has been very active. Glass insulations were found to be unusually versatile, and a large number of types were developed including continuous filament for wire covering, sleeving, tape, cloth, matting, rope, twine and cord Glass products are usually impregnated with one of the common varnishes to develop maximum electrical and mechanical characteristics. The use of glass on high-temperature equipment was extensive. However as glass, alone or impregnated, is not a suitable high-voltage insulation, its primary use was on low-voltage equipment as conductor and ground insulation. When fabricated with other insulation, such as mica and asbestos, difficult applications were made possible, particularly those involving high humidity and high temperature

The electrical industry has been searching for years for a stable high-temperature varnish for bonding inorganic materials such as mica, glass, and asbestos Silicone materials are now under active development for this purpose and are finding ready applications where temperature and moisture conditions are important application factors As silicone materials are treated at 165° to 250°C, organic materials such as paper, varnish, cotton, etc , cannot be used in the construction of the insulation, even in small amounts, as such temperatures carbonize the organic materials and impair the insulating qualities of the composite insulation Silicones are still very costly in relation to organic materials but where advantage can be taken of increased operating temperature in the design, a much smaller machine for the same horsepower results When compounded with glass, mica, and asbestos, silicones provide unusual resistance to high temperature and moisture Motors have been running on severe thermal-aging test cycles of load and temperature for thousands of hours at 300 deg C, without failure Powerhouse auxiliary-drive motors that must operate in high ambient temperatures have benefited from silicone An operating coil of a magnetic contactor designed for 100 per cent duty with silicone insulation was fitted into the same space occupied previously by a coil built for 70 per cent duty Silicone insulation, while not a cure-all for insulation problems, definitely ushers in a new era in insulation performance

Rotating Regulators (233-260)

Electrical control has always been characterized by the ease with which small quantities, such as slight changes in current or in voltage, can be made to control the action of large devices such as motors, generators, etc For example, to regulate the output of a simple direct current generator, it is merely necessary to vary the excitation only about one per cent of the total generated power To change the speed of a direct-current motor, a change of a relatively small field current suffices By far the largest portion of regulated equipment centers around the speed control of one or more rotating machines in the system regulated, and many regulation problems are solved by devising means of changing the speed of one or more of the machines at will The ordinary direct-current motor has a speed range by field control of as high as 6 to 1 By combining several machines, as in the variable voltage system, it is possible to go up to 20 to 1. Rotating regulators extend the range to as high as 120 to 1 when applied to variable voltage drives.

In the successful operation of any regulating means, it is necessary that the apparatus be capable of comparing the actual value of the quantity being controlled with the standard or calibration value desired. If there is any difference between actual and desired quantities, the regulating device must supply power of the correct magnitude and direction to eliminate the difference In other words, the regulating means must measure a certain quantity, compare it with a standard, and if the two are not equal initiate means for equalizing them

Rotating regulators are ideal for many applications and are used for (a) regulating the voltage and current of electrical machines to maintain a selected or changing value, with forcing action and quick response, (b) controlling the speed of direct-current motors accurately over a wide range, matching the speed of one drive with another or holding the speed constant regardless of load variations, (c) maintaining constant tension or constant torque on a wide variety of roll, reel, draw, hoist, and similar applications with improved performance and greater selective range, (d) limiting loads on electrical and mechanical equipment to predetermine values for protection against excessive peaks or unsafe stresses, (e) increasing acceleration and deceleration rates of high inertia loads and giving more uniform performance without current peaks, (f) accurately positioning mechanical equipment, devices, or materials such as machine tools, tracer mechanisms, and alignment stands, and (g) regulating the power factor of synchronous machines and the power input to furnaces, welding heads, and similar equipment to create better system load factor and efficiency

These regulators have been used in over 500 different applications, of which some of the most important are dynamometers with automatic speed regulation and automatic load division between motor and brake, arc furnaces with automatic control of power input by accurate electrode positioning, high frequency generators of 960 to 9600 cycles with automatic voltage regulation, wire insulating machines with constant tension on reels, blast furnace skip hoists with accurate low speed for dumping, cold brass mills with constant tension on winding and unwinding reels, cold strip mills with speed and tension control, electrolytic tinning lines with plating current proportional to line speed, paper calendars with wide speed range and regulated low speed for threading, paper machines with accurately maintained section drive speeds, paper machine reel drives with tension control on reels, paper machine auxiliary wet end drive with constant torque over wide operating speed range, textile slashers with constant yarn tension maintained on the beam; adjustable voltage planers with 30 to 1 speed range with good regulation, feed drives on boring, milling, and drilling machines with 120 to 1 speed range to eliminate gearing; centrifugal casting machines with speed regulation and controlled acceleration and deceleration, mill hoists with provision for accurate landing speeds and controlled acceleration and deceleration to maintain current limit; shovels and draglines with controls on the hoist, crowd, and swing motions to provide fast operating cycles and eliminate peak loads, and many others.

Motor Control (261-368)

The advantages of distributing electrical energy in industrial plants in the form of alternating current are well known. However, many applications require speed change and speed control that cannot be obtained through the use of alternating-current motors Single-phase and polyphase squirrel cage induction motors are essentially constant speed machines, and speed can only be changed by changing the supply frequency or the pole grouping A number of frequency changing systems have been developed, but they are complicated and expensive Single purpose, multi-speed motors on which the base speed is set by pole grouping have also been used for specific applications Polyphase, wound rotor induction motors have been used extensively for variable speed service where the speed ranges are low, in the order of 5 to 1 However, they are better suited to the upper part of the speed range as the efficiency is low in the low part of the speed range Up to about 80 per cent of the speed range, wound rotor efficiency is less than a variable voltage system, which makes it less attractive for general industrial applications

However, the wound rotor motor has been extensively used in alternating-current crane control systems with outstanding success These systems fall into definite classifications, depending on the application. Reactor type control, direct-current dynamic control, alternating-current dynamic control, counter torque control, reversing plugging control, and floor operated systems meet the exacting requirements of all crane jobs Simple hoist, bridge, and trolley operations as well as most rigid hoisting requirements can be met with the various controls Loads can be spotted accurately, inching operations requiring only one quarter turn of the motor shaft are possible, and high-speed or slow-speed operation is possible with light, heavy, or varying loads

Mechanical converters and both electric and hydraulic variable speed couplings have been developed for use with constant speed motors, but their efficiency is usually lower than the wound rotor motor

Where high overall efficiency is desired, the variable voltage system (Ward Leonard) is the accepted method of obtaining speed ranges in excess of 6 to 1, with 20 to 1 being about the maximum range This range is obtained by a combination of generator voltage and motor field control The amount of field control is limited by

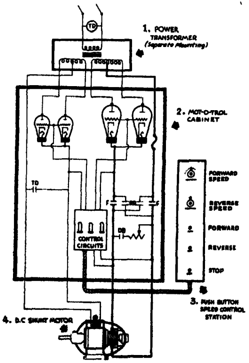
Automatic electronic control system makes possible increased productivity of machine tools.

motor stability, and the amount of voltage control is limited by speed regulation and maximum torque. The addition of regulating devices and other refinements to improve the characteristics of this scheme make it possible to extend the range above 20 to 1.

The electrical drive for a wide speed range is obtained by the addition of a rotating regulator to a conventional variable-voltage system. This combination will give a speed range of 120 to 1 or more and can be used effectively in many industries to simplify the mechanical design of the machine it drives. Its use eliminates an elaborate gear changing mechanism, clutches, coupling, etc., and at the same time gives a more flexible control scheme so that the operator can control the complete speed range without leaving his work or stopping the machine.

The increase in speed range has been accomplished by widening the range of voltage control, the range in field control remaining not more than 4 to 1 and preferably 2 to 1. This type of drive is best suited to a load which has constant torque characteristics. The machine tool industry has many applications of this type, and it is here that the wide speed range has been applied. Feed drives on boring mills, milling machines, automatic screw machines, etc., have constant torque characteristics as the load consists mostly of overcoming the friction of moving parts.

The development of wide-speed variable-voltage drive required the compensation of certain characteristics at the low speed that are not important at high speeds. The two most important factors are residual voltage of the generator and the IR drop of the system. As the residual is a function of the previous magnetic history of the generator and as the speed of the direct-current motor will drop as load is applied due to the IR drop in the system, a sensitive rotating regulator or regulating generator was applied to effect proper correction.



Basic elements of electronic motor control.

The variable-voltage system is without peer for drives requiring a close control of speed over a wide range. For extremely wide speed ranges, from 200:1 up to 1500:1, servo-mechanisms have been incorporated to provide accurate speed control. Such systems have been primarily applied to machine tools where accurate positioning of the tool and work are required. For work of lower power, the scheme is often ruled out, however, because as the size decreases, the cost of the exciter and direct-current starting equipment becomes an increasingly large percentage of the total. A simplified version of variable-voltage control offers to those applications requiring a few horsepower most of the basic advantages of the full-fledged scheme without its complications or cost.

The system calls for only three standard rotating machines: a squirrel-cage motor and two series-wound direct-current machines. The direct-current machines can be duplicates, one to be used as a generator and the other as a motor. The self-excited direct-current generator is driven in any desired manner by the alternating-current motor, usually direct connected. The armatures of the direct-current generator and motor and their respective series fields are all connected in series. To reduce the motor speed, the generator field is simply weakened by shunt resistance. By this means good speed regulation, except at light loads, is obtained over a speed range of 10 to 1. Typical applications include conveyors, kilns, machine tool feeds, stokers, feed water pumps, bottle making machines, wire drawing, glass drawing, etc. This adjustable speed drive combines the desirable high-torque characteristics of a series motor with the flat speed characteristic of a shunt-wound machine.

Electronic Motor Control (369-408)

To fulfill the desired requirements of an alternating-current adjustable-speed motor of wide speed range, the electronic motor speed control was developed. In general the system consists of a single or polyphase grid-controlled thyratron tube rectifier that takes power from an alternating-current line and rectifies it into direct-current output. The rectified direct-current voltage is applied to a regular shunt-wound direct-current motor and may be varied from zero voltage to motor-rated voltage (or above) for direct-current armature control. Smaller thyratron tubes provide rectified direct-current field current for the motor. The field voltage is held constant throughout the range of armature voltage and then is reduced to provide greater speed range by field weakening above the base speed of the motor. For small motors, single-phase full-wave rectification is used on both field and armature.

Speeds may be pre-set within the design range. With two-speed control potentiometers and reversing contactors, different forward and reverse speeds may be preset so that pushbutton operation, for pre-set speeds in either direction, is obtained. Speed adjustment is nonstop and may be made at any time while the motor is running. Speed control over the full range is usually incorporated on a single dial.

All of the speed adjustment and speed regulation functions (exclusive of field weakening), either manual or automatic, as well as current limitations, are accomplished by varying the motor armature voltage. This varying voltage is obtained by advancing or delaying the firing point of the rectifier tubes on the alternating-current voltage wave, thus permitting only a certain definite portion of the alternating-current voltage wave to be rectified into direct-current voltage. The normal speed range by armature control is 20 to 1 below the base speed of the motor, though a much wider speed range such as 100 to 1 can be obtained. Field control is used above basic speeds for standard motors, which is normally 2 or 3 to 1. In a properly adjusted system, the speed over a 10 to 1 range will not vary more than 4 per cent from a presetting or more than 8 per cent on a speed range of 20 to 1.

The control is arranged so that the motor is always at full field, regardless of the setting of the speed potentiometer. If the speed is above base speed, with weakened field, the speed control does not become effective and the field is not weakened until the motor reaches base speed. Fast, smooth acceleration is obtained through a special current-limiting device built as a part of the standard unit. The current-limiting device also works from a small auxiliary control tube which, in turn, controls firing of the rectifier tubes. Thus, the voltage output of the rectifier will be such that a preset limit will not be exceeded. Dynamic braking of the motor is accomplished by inserting a braking resistor at the desired time.

Applications of electronic motor controls have been very extensive in both fractional and integral horsepower sizes and include fuel pumps, conveyors, lathe drives and feeds, bottling and packaging machines, ironers, gear cutting machines, glass drawing machinery, straightening machines, spinning or flanging machines, cold or hot saw feeds, ore concentrators, wire shakes and filters, cutters, slitters and winders on paper machines, reels, top roll drives, bag machines, folders, creasing, perforating, and embossing machinery; laminating and coating machines, coal feeders, stokers, printing presses, textile wrappers, winding reels, and many others.

Induction and Dielectric Heating (409-492)

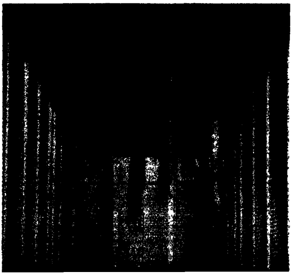
The need for high production accelerated the application of induction heating to the preheating, melting, annealing, and heat treating of metals. In these processes, frequencies from 80 to 15,000 cycles have been used, and the power required has generally been obtained from rotating machines. The advantages of induction heating are many, but those most influential in its preferred use are.

1. The heat input can be closely controlled.
2. No physical contact is required between moving or stationary work and electrical circuits.
3. The heat may be localized on internal or external services as desired.
4. The depth of heating may be controlled by frequency and time.
5. For melting applications, melting occurs with agitated action, thoroughly mixing the metals or alloys and adapting them to high speed production work with resultant savings in handling and conveying of materials.

Variable speed motors and reduction gear units drive the winders and dryer sections on many modern paper machines.

Dielectric heating gives a shiny corrosion resistant finish to a strip of tin plate; here temperature is checked.

Welding side panels to frame of a big truck trailer is made easy and fast with this resistance welding outfit.



Certain generator frequencies have been established through usage The most common are 960, 3000, and 9600 cycles, with 1920 and 4800 cycles being used for special applications. Generator ratings range from 35 kw to 1500 kw, 960 cycles, 50 kw to 1250 kw, 3000 cycles, and 20 kw to 500 kw, 9600 cycles These generators usually consist of an inductor type generator driven by a synchronous, induction, or direct-current motor. Types of generators recently developed include air cooled, water and air cooled, or water and hydrogen cooled Most sets are 3600 rpm and are designed for 400 to 800 volts single phase.

New generators recently announced include a 30,000-cycle motor-generator set Few applications in the low frequency field require a frequency higher than this, and the new development extends the frequency coverage to as high a point as is now considered necessary. Tube oscillators have previously been used to supply power at frequencies above 10,000 cycles for most applications

Peak demand in welding is lessened by energy storage systems; magnetic type stores energy in transformer core.

Radio Frequency Heating

Aside from a continuation in the great volume of experimental work on the use of high frequencies for heating, an essential step has been taken in the development of high frequency induction and dielectric heating. The needs for generators of high frequency power have crystallized to the point that engineers have created standard units It is no longer necessary to have a generator designed to serve a given purpose Most needs can be served well—and with all the advantages of standardized units—by the range of powers and frequencies available in the accepted family of units The smallest size industrial unit has an output of but 2 kw, the largest 200 kw Between the units of 2, 5, 10, 20, 50, and 100 kw Ratings of 5, 10, 20, 50, 100 and 200 kw are available for induction heating at a frequency of approximately 450 kc For dielectric heating, ratings are available from 2 to 100 kw at a frequency of approximately 13.6 megacycles and in the smaller ratings, 10 kw and below, optional frequencies of 5 and 30 megacycles are also available by simple substitution of standard tank circuit assemblies

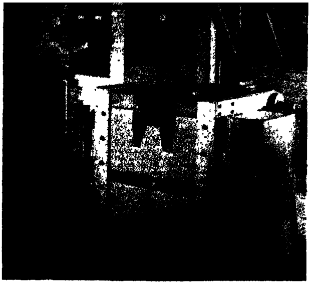
The acceptance of high-frequency oscillators by industrial engineers has undoubtedly been delayed by false thinking that such units were too complicated for industrial workers to handle. Designers have done much to dispel this thinking by providing generators that not only look simple but are simple to operate Stock units are self contained up to and including 20 kw requiring only a connection to a power source to operate

Automatic timing control permits load-cycle adjustments to a predetermined time, which can be automatically repeated Where the application of the larger ratings indicate the desirability of automatic load control, this can be provided to meet the application requirements

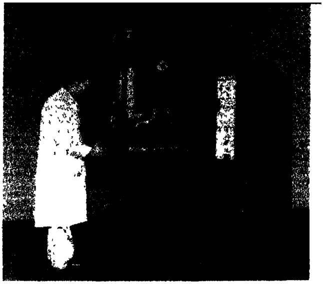
The high-frequency heating laboratories have been going full tilt, exploring the possibilities of radio frequency heating of many products While the use of high frequencies does not provide the answer to every heating problem, for many the advantages are striking. An excellent example is the application of a 2 kw

High frequency induction heater preheats horseshoes to 1200 deg. F. before resistance-welding calks to the shoe.

Second type of energy storage system for welding is the capacitor type which stores energy in a bank of capacitors.



Induction melting furnaces are widely employed for alloy steels.



Mounted on the side of the resistance welder, the synchronous welding unit is indispensable to its operation.

oscillator in the manufacture of plastics A great many molded articles like electrical plugs, sockets, switch housings, magneto covers, etc, are molded from a preform made of the plastic material which is placed in a hot mold, heated, and then subjected to high temperature and pressure for a curing period By using high frequency to preheat the preforms, the preforms can be placed directly into the regular mold, and because of their semi-plastic state from the high frequency heating, it is not necessary to use the high pressures now required in compression molding These lower pressures mean that smaller, less expensive presses can be used Correspondingly, the initial cost of molds is less, their maintenance charges less, and they last longer Preheating also reduces the time necessary to cure the material, which permits larger and quicker production from smaller capacity molds, thus effecting a saving in the original cost of the molding equipment Radio frequency dielectric heating is also finding wide application in other non-metallic fields such as bonding and curing of plywood, heating and curing of synthetic plastics, curing of rubber, cooking of breakfast cereals, twist setting of textiles, and many others

Radio frequency induction heating has also been expanding rapidly into industrial fields Metal heating applications are numerous and cover annealing, hardening, brazing, sintering, forging, and soldering Unusual production increases and material savings have saved plants many thousands of dollars Unusual applications indicate the versatility of this new industrial tool. Electroplated tin, one third its former thickness, is now flowed on steel sheet at rates up to 1000 feet per minute, by inductively heating the rapidly moving strip to the flow point of the tin Over 8300 kw of 200-kilocycle generators have been installed in seven plants for this service alone. Hacksaw blade teeth may be hardened with high frequency heating supplying 8500 BTU per hour (equivalent to 2½ kw) for producing 36 hardened blades per minute. Gears of many types may now be surface hardened by induction heating with accurate control of depth of penetration resulting in uniform case hardness and thickness. Brazing and soldering of parts is gaining in popularity as heat is generated only at the brazing point, widening the field of alloy and complicated assembly fabrication. New applications are being developed as the advantages of improved product and increased production are realized

Resistance Welding (493-533)

The practice of resistance welding is not new For many years only steel was resistance welded, and heat was so generously applied as to practically allow forging as well Automatic weld timing, when employed, was measured in seconds The process was largely confined, therefore, to the coarser sheet steel structures which tolerated such undesirable welding aftermaths as severe electrode marking, warping, blacking, and sealing

Within the last several years, however, resistance welding has become a precision process It has been extended to a wide variety of the modern alloy metals such as stainless steels, brasses, bronzes, and to non-ferrous metals of sharp fusion point such as aluminum It has found application in almost every metal fabricating industry for both sub-assemblies and body assemblies In the aircraft industry, in particular, it has speeded production and cut costs by reducing the need for rivets

Resistance welding is done by practically short circuiting the secondary of a high-current transformer, producing up to 10,000 amperes in the process This being the case, accurate automatic timing of the duration of the flow of current is necessary to prevent burning or warping the metal In general, to make a resistance weld we must control (1) the amount of current passed through the work, (2) the time this current is allowed to flow, and (3) the timing and degree of electrode pressure

To perform these three functions singly or in any desired sequence, a large variety of equipment and devices has been developed Over a period of years, resistance welding control units have been designed to meet specific needs as they arise Each unit was suited to its job without particular reference to common physical forms or dimensions All these controls have now been co-ordinated into one family of units with the resulting convenience of operation, maintenance, and versatility. Each unit consists of a few sub-assemblies of standard basic dimensions and several standard cabinets to house them. The various functional sub-assemblies are combined in a hinged frame and are plug connected for quick replacement. Thus all control apparatus is mounted in one cabinet, affording easy accessibility for installation and convenient maintenance

The commonly used sub-assemblies are. heat control and ignition firing control, spot timer, spot pulsation and seam timer; fully electronic seam timer, electromechanical seam timer, two types of sequence timers, non-synchronous heat controls and voltage and current regulators All control apparatus needed is mounted in one standardized cabinet that can be mounted on the floor or on the welder The overall result is a unified design permitting many improvements in operation.

In single-phase resistance welding applications, high peak kva is drawn from the line with resultant possible high voltage drop, which may produce light flicker and other reduced voltage problems. To help reduce this peak kva demand and to provide desirable equipment features not found in single-phase alternating-current welders, a new method known as the energy storage system has been developed. Its basic principle is to draw energy slowly from a three-phase line and store it until the weld is made Two types of stored energy welders have been developed—the magnetic type which stores energy in the iron core of the welder transformer, and the capacitor type which stores energy in a bank of capacitors These controls include the required ignitron rectifiers, ignitron contactors, capacitors, and heat and cycle controls for application directly to the welding transformer. The rate of energy release in these welders is very high, as the weld current is produced by breaking current in a highly inductive circuit or by discharging capacitors. This characteristic has been put to use in welding alloys, particularly those which have high heat conductivity or those which have low melting points.

Arc Welding (534-559)

The use of arc welding, both alternating current and direct current, expanded tremendously during the war. At the height of the shipbuilding program in 1944, it was estimated that welders were depositing 100,000 pounds of welding electrode metal a day By far the greatest demand was for single operating welding machines in rating from 200 to 400 amperes, either engine or motor driven, and this apparatus was developed to a high state of perfection. To meet Navy requirements, unusually small high-capacity machines were developed One 200-ampere light-weight welder weighs just 333 pounds as against 500 pounds for a 150-ampere standard welder.

For use in shipyards and factories where large blocks of welding power were required, large high-capacity 1500-ampere multiple operator direct-current units were developed. Each welding circuit required an air-cooled adjustable resistor for control of welding current. These, were bulky and presented space problems in restricted areas. A new multi-welder panel with liquid-cooled resistances providing ten operator outlets was developed to provide portability and flexibility. The cooling medium, a non-inflammable liquid, circulates by convection through two radiators, each controlled by a motor-driven fan. All of the outlets can be used at one time, and each operator can change his current values at will

Automatic welding, using the Unionmelt process to weld thick sections, also came into extensive use Welding rates reached 125 pounds per hour by deposition as against about 6 pounds per hour by manual welding.

Early in the war alternating-current welders were developed for use in industrial work. These equipments were accepted slowly at first, but as electrode and welding techniques were developed, they became extremely popular For special applications, high frequency arc stabilization increased the speed of welding and produced improved welds.

To meet the need for welding a large variety of metals, welding electrodes of many types were developed. Coated electrodes, to provide a protective atmosphere at the work, were developed to a high state of perfection Alloy electrodes of innumerable compositions were introduced to make welding of special alloys possible

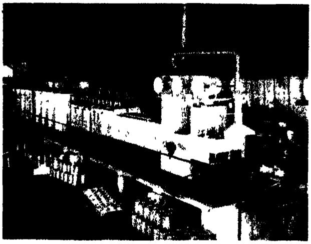
Many special welding auxiliaries were developed to make the welder's job easier Magnetic work holders, high intensity lamps to enable the welder to see the point where the arc was to be struck through his heavily tinted helmet window, electrode holders with built-in control buttons for starting and stopping the welding machine or setting the current, portable tack welders, lighter welding cable. improved safety helmet gear, and safe, non-inflammable welder's clothing all found wide acceptance and made the welder's job safer and easier.

Brazing

Brazing is an old, but still not too generally used, method of joining members of copper, brass, bronze, or various alloys. One handicap has been the difficulty of transporting the flame brazing or electric brazing apparatus to the job Small, light-weight, self contained portable units for joining wire cables, strap connectors, pipe, etc., have been developed that require only a connection to a 220-volt source to place in operation These sets consist essentially of a transformer for providing high currents at low voltages, suitable voltage selectors, controls, and carbon tipped prongs that can be clamped over the pieces to be joined High current flowing through the carbons heats them to incandescence, quickly bringing the material to a brazing temperature of from 1200 to 1500 deg. F. Three sizes—5 kva, 625 amperes, weighing 30 pounds; 10 kva, 833 amperes, weighing 100 pounds; and 20 kva, 1667 amperes, weighing 250 pounds—provide equipment to meet the needs of most hand brazing jobs.

Electric Furnaces (561-583)

The tremendous production of metallic parts requiring annealing, hardening, heat treating, or furnace brazing could never have been achieved without the extensive development and application of the electric furnace. A high proportion of all electric furnaces manufactured incorporated protective atmospheres within the furnace to prevent oxidation, scale, and discoloration. Such furnaces were usually designed for full automatic control, even to the loading and discharging of the furnace. Automatic continuous gas analysis and con-



Manufacture of copper and copper products requires use of annealing furnaces such as this one.

Ball type electric furnace is used in the automotive industry.

Automatic welding by the Unionmelt process is here utilized in fabricating small tanks.

Arc welding is still the most widely used of all electric welding processes.

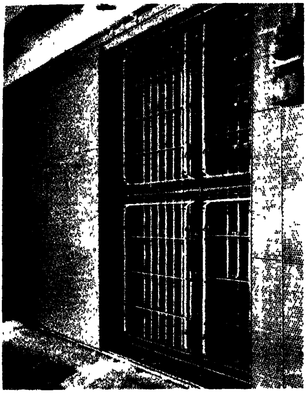
trol, automatic heat control, and automatic charge cycling were outstanding features which gave consistent, reproducible results

During the war, furnace brazing was developed to a high state of perfection In this process the parts to be joined are formed to close tolerances and completely assembled with rings, sheets, rods, or otherwise formed brazing material which is placed at the joints The assemblies are then mass loaded into a controlled atmosphere electric furnace and brought up to brazing temperature. The brazing material melts and is drawn uniformly into the joints by capillary action, producing an assembly that is strong, durable, and gas- and liquid-tight. The process is so uniform that as many as 15 concealed joints have been made on assemblies with as low as 0.01 per cent defective. Tolerances may be held to very low values, which eliminates many machine operations or makes possible the use of pre-machined parts.

Electric arc furnaces were extensively developed and applied in melting operations during the war. Such installations now use more kilowatt hours of energy each year than any other industry except the electrochemical industry. The control of power supplied to arc furnaces has been a difficult problem of long standing, as the power requirements during the early stage of melting are extensively variable and very large power swings develop Very efficient regulators of the rotating type have been developed to control the electrode position in a manner to give maximum power input to the furnace and at the same time reduce the power swings to negligible factors For small furnaces mechanical regulators have been extensively and satisfactorily applied

Electrostatic Air Cleaners (584-591)

For many industrial processes, clean air is essential. In many plants the dust particles are conductive and affect the insulation of electrical equipment. The life expectancy of the windings of motors and generators in steel and metal working plants is especially susceptible as fully 85 per cent of the dust results from small carbon particles and metal slivers which are much too small to be trapped by mechanical filters. In the electrostatic cleaning method, all air-borne particles pass through an electrostatic field adjusted to produce voluminous amounts of free ions. The individual dust particles become ionized (electrically charged) and are precipitated on collector plates which are oppositely charged. The efficiency of electrostatic air cleaning is very high as it delivers air which is 300 to 400 per cent cleaner than air delivered through conventional mechanical filters.



Intake side of electrostatic precipitator that cleans 40,000 cu. ft. per min. of cooling air for inductive heating equipment.

Where extreme cleanliness is necessary, electrostatic air cleaners have no peer

The first industrial installation of electrostatic air cleaners was made to the air cooling and ventilating systems of motors and generators in steel plants in 1940. This idea has been extensively accepted, and a large number of installations were made in the last few years In addition to steel plants, installations have been made in textile plants, precision ball bearing plants, rayon and nylon plants, optical plants, power generating stations, bottling plants, paint and varnish plants, food processing plants, telephone exchanges, control rooms, chemical plants, cement plants, machine tool plants, and many others For machine tools, special electrostatic air cleaners were developed to remove oil mists attendant to grinding, milling, shaping, etc Such cleaners reduced the fire hazard and improved cleanliness to a point that plant maintenance was appreciably reduced Large amounts of oil coolants were also saved as precipitated liquids were returned to the system

Trends of Future Developments

The war had no particular effect upon the fundamental principles of engineering, which is a continuing and progressive science However, it did advance by many years the development and introduction of new materials, devices, and manufacturing techniques, which could be efficiently used in many industrial fields Engineering for tomorrow is likely to bring two important developments. first, improved materials that may increase the efficiency and decrease the size of individual pieces of equipment and second, the development and utilization of control devices to better the performance of existing machines and increase production.

Illustrations for this chapter were obtained through the courtesy of Westinghouse Electric Corporation, General Electric Co, Reliance Electric and Engineering Co, and Federal Press Co

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CHAPTER IX

ELECTRONICS

by VIN ZELUFF

Nearly everyone has seen electronic tubes in radio receiving sets, transmitting sets, and X-ray machines In their operating principles, these tubes are exactly like those used in industrial electronic equipment, in fact, many ordinary radio tubes are used in electronic control units These tubes and their larger versions have been put to work in factories, shops, mines, and mills

Electronic tubes today do such operations as control of electric motors, speeds, process control, sorting, protection of equipment and personnel, heating both metals and insulating materials, inspections, measurement, color matching—in fact, practically every job that a man or machine could do, performing the job more efficiently and precisely than has ever been done before.

Electronic Measurements

Today a factory worker can measure the diameter of a piston or check the frequency of a quartz crystal with the range of a few parts in a million, a degree of precision accomplished with ease and brought about by electronic tubes Thousands of electronic measuring devices are in use today in every branch of industry, giving hitherto unobtainable and almost incredible accuracy (1, 2). The precision of the simple and basic machinist's micrometer has been increased several times by using radio tubes to detect the instant of contact The tube is far more responsive than even the sensitive touch of a skilled operator Lengths and thicknesses can be determined with gages whose scales can be read several feet away to fractions of a ten-thousandth of an inch. The position of the measuring spindle may move capacitor plates or alter the electromagnetic structure of a coil, with electronic tubes amplifying the resulting change and actuating an indicating instrument (3, 4, 5).

Weight measurements have likewise been revolutionized by electronics Amplifiers and electronic tube accessories have been applied to scales and balances to increase the sensitivity and minimize the strain and concentration of the operator making the readings Electronic amplifiers are used extensively with strain gages to measure the bending, pulling and vibration stresses to which various structural members in aircraft, cranes, ships, and other structures, both large and small, are subjected (6). It is estimated that over 500,000 of these gages are used every year in various industrial applications for the measurement of mechanical forces, weight, and small motions. The strain gages themselves are simply rectangular grids of resistance wire, supported and held in place on the object being studied by a film of elastic cements. Stretching and compressing of the structural member and its gages wire directly affects the electrical resistance of the wire This is a quantity that can be measured and recorded with high precision by electronic equipment

The list of electronic instruments includes time interval meters for measuring accurately the time from one impulse of light, sound, current or voltage to the next, for intervals ranging from 1/10,000 of a second up to 3 seconds, a mercury-vapor detector that measures one part of mercury in 200,000,000 parts of air, photoelectric recorders so sensitive that 1,000,000 of a millionth of a watt will cause full-scale deflection of the inking pen; photoelectric spectro-photometers capable of making such accurate chemical measurements as one part of silver in 250,000,000 parts of solution, and on through hundreds of other applications for measuring moisture, temperature, speed, vibration, sound level, noise, voltage, current, illumination, color, and all the other quantities in which the industrial engineer is interested

Motor Controls

But electronics is used far more than to measure accurately in industrial plants, it controls machinery as well Machine tools of many types have been equipped with electron tube equipment (7, 8)

Many manufacturing plants employ machinery driven by electric motors whose speed can be changed at will by the operators For this purpose, a-c motors are not suitable and d-c motors must be used Alternating current must be converted into direct current to operate such motors This is now being done electrically in such a manner that many additional advantages are provided, such as extremely stable speed range, good speed regulation, and smooth automatic acceleration

This job is being done by a tube called a thyratron (9, 10, 11) With it, the motor speed is automatically regulated so as to maintain a practically constant speed at any setting regardless of the load. Other small tubes control the output voltage of the main thyratron tubes to compensate for changes in speed. Thus, vibration difficulties sometimes encountered with adjustable-speed drives are minimized with electronic arrangement since the d-c motor is the only rotating part The electronic equipment is available in its own cabinet or may be mounted in the driven machine.

Motor control equipment (8, 11) has been applied in many industries handling materials on feeder and assembly conveyors. In the machine tool industry (12, 13), grinders (14), milling machines (15), turret lathes, and gear-cutting machines utilize electronic motor control to advantage (16, 17). Rotary cutters, slitters, and winders are only a few machines in the paper industry that have been equipped with the new speed controls

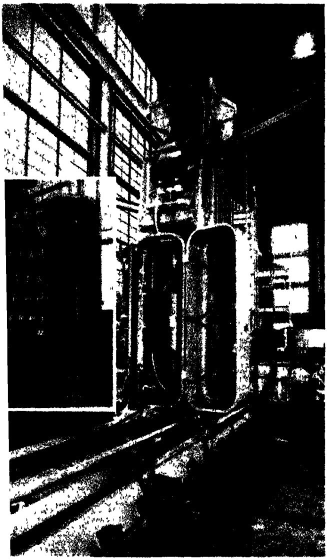
Electronic motor control offers many advantages to the grinding machine operator (14). Efficiency is highest in a grinder when the pressure of the work against the wheel is constant at a value corresponding to maximum cutting capacity Electronic control of the infeed of the grinding wheel provides automatic variation of feed motor speed to maintain this optimum rate of cutting Smoothly adjustable low speeds eliminate stopping to change speeds Control of the speed is achieved by adjusting a small knob mounted in the most convenient spot on the grinder, a distinct advantage over the bulky rheostats otherwise used with direct-current motors

Electronic control for the head-stock motor of a cylindrical grinder is being widely used to turn the work at the required varying speeds during plunge cut grinding, giving a smoothly finished product without surface irregularities at each speed-changing point.

Surface grinders having separately driven rotating tables and reciprocating wheel heads can be electronically controlled to give practically constant surface speed at the cutting point As the wheel approaches the center of the chuck, both the chuck rotation and the wheel head speed are automatically increased by the tubes that feed the drive motors

Electronic control for grinders generally involves redesign for maximum effectiveness The modernized design reduces the number of rotating parts, thereby reducing vibrations and permitting higher production speeds In addition, the wider speed ranges possible with electronic control mean finer finishes and higher precision without sacrifice of automatic operating features. Cam-actuated potentiometers can be set up for a particular job by tool-room personnel or the operator himself, or the drive torque can be measured electronically and used to maintain the desired constant value of torque

The operating characteristics of existing grinders can



Combination boring, milling and planing machine with a Rototrol speed regulator and a different synchrotie. Inset shows compact arrangement of control and motor set.

Temperature of furnaces and kiln can be controlled by a photoelectric pyrometer; current from phototube is amplified to operate a recording thermometer.

also be greatly improved by the addition of an electronic motor control. For example, the replacement of overhead drives with individual electronic motor drives on three 30-year old grinders by one manufacturing company permitted precision finishing of hardened pump liners to a tolerance of 0 001 inch despite variations in both liner materials and sizes (18). The closely regulated stepless speed range of 20 to 1 provided the desired tolerance and finish without difficulty

The typical electronic drive consists of an electronic rectifier for changing alternating current to direct current, plus control tubes that vary the output of the rectifier in response to a potentiometer no larger than the volume control on a radio receiver This combination of tubes placed between the alternating-current line and the conventional direct-current drive motor, gives the desirable characteristics of d-c motors without need for d-c wiring throughout the factory

To mention a few other machine tool applications, machining of aluminum spar beams for plane wings was reduced from thirteen and a half hours to five minutes through installation of an electronic motor control system on a large automatic contour milling machine Similar equipment installed on an automatic lathe used in cutting a precision spiral groove in the end plates of a cartridge reel reduced production time from forty minutes to twelve minutes per piece

Electronics have important applications in the machine tool field for speed control and sizing of parts. Controls on this lathe are mounted on slide drawer for ease of access.

Timing Equipment

Electronic time-delay relays (11), capable of timing intervals as short as 0 05 second or as long as several minutes, are marketed as complete units ready to install on such machine tools as welding machines, honing machines, grinders, and molding machines for such applications as processing, cycling and sequencing Adjustment of timing is done with a single knob, to any desired interval in the available range of the timer With tubes used here to cut off the power at the end of the operating interval, relay troubles are eliminated, with consequent greater dependability and longer life.

"Electric Eye" and Counters

Photoelectric equipment, commonly called the "electric eye", is widely used in industrial operations (8, 11, 19, 22, 23, 24) It utilizes light beams and phototubes and is available in many different types of packaged units These are used to prevent machines from injuring workers or from damaging themselves (20) For example, when an automatic punch press fails to eject a punched product before the next sheet is fed, the die may be ruined if the press closes on two pieces A light beam is directed across the press bed to a phototube which connects to controls geared to the press so that jamming of a piece interrupts the light beam and the phototube stops the press This type of equipment is also utilized to protect a worker by having the machine remain inoperative so long as his arm or body interrupts the light beam shining through a dangerous area.

Any moving objects capable of interrupting a light beam can be counted electronically If the objects are on a moving conveyor belt, the beam is simply directed across the top of the belt at the proper level for interception, and the phototube amplifier is conected to an electromagnetic counter (8, 11, 21).

Electronic counting is most useful in connection with objects that for some reason must not be touched during the counting process. Examples are counting of freshly painted objects, fragile glass objects like electronic tubes, sterile articles, delicate sheets of paper moving at high speed through printing or folding machines, unpackaged foods and meats, people or animals passing a given point, flashes of light such as those due to flashover on generators, and counting irregular-shaped and lightweight objects that could not readily be positioned to actuate mechanical counters reliably

In the manufacture of one type of tubing made of soft clay, the material is so soft as it leaves the forming machine that a taut wire must be used as a shearing knife to cut it to size. A mechanical limit switch set at the outer limit of the proper measurement and used to actuate the knife was found to mar the soft end of the tube and became gummed-up within a short time by the clay A photoelectric relay and light beam have been found indispensable for the job. When the clay tube extrudes to its proper length, it interrupts the light beam and the photoelectric relay causes the shearing knife to operate Since only a beam of light is involved, the disadvantages of the mechanical components of the former method were eliminated.

Whether electronic counters are preferable to simple mechanically actuated counters, or to lever-operated switches serving electromagnetic counters, depends upon production conditions in relation to articles outside the untouchable category. Electronic counting eliminates the accurate positioning requirement of other methods because the object can interrupt any part of the light beam The cost of an installation, in many instances, is under a hundred dollars since packaged electronic units made by mass-production methods are suitable for most jobs Maintenance is no problem because the equipment consists of only a few parts, in addition to the small lamp used as the light source, the phototube and one or two radio-type vacuum tubes

Metal Detectors

In sawmills, electronic metal detectors may be used to reveal the presence of spikes and other metal objects in logs, and stop the saws when such foreign objects approach the cutting zone (25) Cut lumber can be examined electronically for nails in a similar way at speeds up to 100 feet per minute Electronic amplifiers give the alarm and actuate a solenoid-type hammer or paint brush that marks the location of the nail imbedded in the lumber Paper mills use similar but more sensitive detectors to reveal the presence of almost invisible metal particles in finished paper or cardboard.

Dielectric and Induction Heating

Electric heat is a means of speeding up production, where heat is necessary The heat is produced directly within the material itself and no heat is wasted in the surrounding atmosphere as in an oven or in heating auxiliary conductors such as metal pots and pans. The heating is done by a somewhat old-fashioned radio station transmitter containing high-power vacuum tubes. These generate electrical power exactly the same as if they were to broadcast a program, but the electrical power is not fed to an aerial or antenna, instead, it is concentrated in the material under treatment and converted into heat The methods of converting this energy into heat are known respectively as dielectric and induction electronic heating (26, 27, 28, 29).

Dielectric electronic heating, also called electrostatic heating, is applicable only to nonmetallic objects, which are placed for a short time between two metal plates connected to the electronic apparatus. The resulting heat is distributed uniformly throughout the thickness of the material without heating the surfaces to any great degree The metal plates apply only the electrical power, and the slight heat that they receive is produced by the material being heated (28).

Nonconductors of electricity, such as textiles, wood, foods, plastics, and glass are heated by this means. An important application of dielectric electronic heating is that of gluing airplane propellers made of layers of impregnated wood (30, 31) Plywood products made in this way can be lighter than aluminum yet handle the loads of heavier metals They usually require metal-working tools for machining, and can be more flame-resistant than steel In a recent test of a plywood product, a cutting torch took 39 seconds to burn through a half-inch sheet, whereas a half-inch steel sheet was cut through in 11 seconds

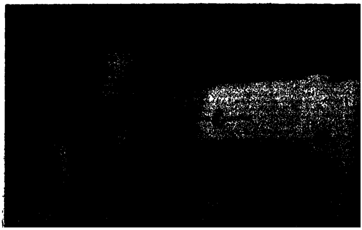
In the manufacture of a laminated wood spar flange for one type of aircraft the innermost part of a piece 25 feet long and 7 by 5 inches in cross section required heating without excessively drying the outer layer Until electronic heating was employed, the spars had to be left in the presses for eight hours A steam heating process also consumed many hours With electronic equipment, the whole heating operation is accomplished in about 30 minutes, with practically uniform temperature maintained throughout the glue lines (32, 34)

In the textile industry, dielectric electronic heating is used to assure uniformity of drying temperature One textile plant reports that electronic drying produces better fabrics and requires only about 2 per cent of the time required by former heating equipment

Thermoplastic sheets are bonded together in a continuous seam by an electronic sewing machine (33) It consists of a pair of rollers, between which the material passes, and which act in the same manner as the metal plates Sheet plastic materials such as Vinylite and Pliofilm are bonded together in a thin, solid and airtight seam that is stronger than the material itself

Thawing and heating a precooked frozen meal with dielectric heating takes only 70 seconds With conventional methods, such as a hot-air oven, the thawing and heating time is never shorter than 15 minutes. This factor alone limits use, particularly in restaurants Since the heating is done in about a minute by electronic equipment, the restaurant can prepare food in off-peak hours, keep its menu in deep freeze and thaw and heat dinners when they are ordered This eliminates much of the waste inherent in present-day restaurant methods of food preparation and saves the restaurant owner from the daily losses which he now suffers because he has to guess his volume of business in advance

1-minute heating of precooked frozen foods is new job for electronics. R-F heating is generated by tube developed for radar.



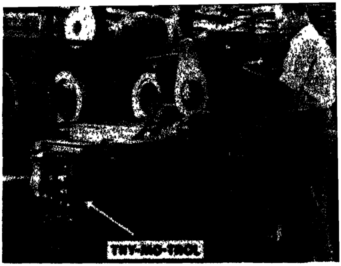
Since electronic heating of food produces the heat from within, the only thing that heats in the electronic oven is the food, not the surrounding air or water as in baking or boiling methods.

This type of food heating is done at ultra-high frequencies. In fact, the Federal Communications Commission of the United States recently assigned a band of frequencies at 915 megacycles for electronic heating. In this range, the usual radio type coils and condensers so useful at lower frequencies are not practical. Instead, microwave "plumbing" consisting of hollow metal pipes and boxes called waveguides and cavities are used. The frozen food is placed on a fiber dish in the cavity where it is subjected to the ultra-high frequency radio waves. The food thaws and heats to a temperature too hot to eat, without any electrical or mechanical constact whatsoever (35, 36, 37).

As designed at present for restaurant use, the equipment consists of a metal cabinet about the size of a household refrigerator. A power switch, a timer, and a foot treadle are the only controls necessary for operation. When the unit is turned on, a 40-second time delay prevents the use of the equipment until the electronic tubes are heated. As soon as a green indicator light turns on, the oven is ready for operation. Heating is done by merely placing the frozen meal in the oven and stepping on the food treadle, from them on, the operation is automatic. The cavity door slides into place, power is applied and the meal heats as long as the load timer dictates. When the heating cycle is over, power is cut off and the cavity door drops down. The operator removes the heated meal from the electronic oven and the machine is ready to begin a new heating cycle. Twelve-ounce precooked frozen diners, consisting of a vegetable, potato, and meat, can be heated from zero Fahrenheit to a temperature too hot to eat in 70 seconds. In addition to defrosting, dehydration and sterilizing of food has proven feasible (38, 39, 40).

The other type of electronic heat is called induction heating and is used for raising the temperature of metallic substances such as iron and steel (41, 42). It involves placing the object inside a coil of heavy wire carrying high-frequency alternating current. For surface hardening of a thin layer of metal and for heating rough, irregular contours of metallic objects, the alternations occur more than 15,000 times a second.

Recording spectrophotometer measures and classifies color, providing a permanent record of colors for matching in textiles, plastics and similar fields.



"Thy-mo-trol" (at left with panel removed) provides a speed range of 160 to 2300 rpm for 1 hp motor of grinder.

Electroplating

One spectacular job accomplished by induction electronic heating is in the tin plate industry, which had to conserve tin when Malayan sources of supply were cut off during the war. Plating of tin was effected by dipping steel plate or sheet into the hot metal. This produced a gray porous surface that permitted the steel under the tin coating to be attacked by acids in the foods. It was found that the tin surface could be made to flow by the application of heat. In the electronic methods, continuous strips of tin plate are fed through a coil, and electrical energy from vacuum tubes heats the layer of tin until it flows and forms a smooth layer 1/30,000th of an inch thick. The electronic method processes 1,300 feet per minute of 30-inch tin plate and saves one pound of tin per 100 lbs. of steel (43).

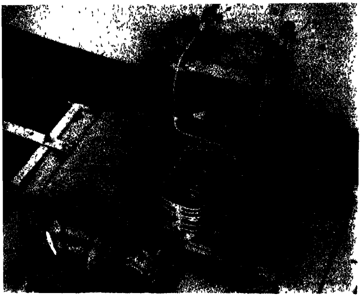
Brazing and Soldering

Many brazing and soldering operations have been improved by electronic induction heating. The main advantages are that the heat acts quickly, can be confined to a small area, and close control is possible. Joints are free of oxidation, heating costs are reduced and semi-skilled operators can be employed.

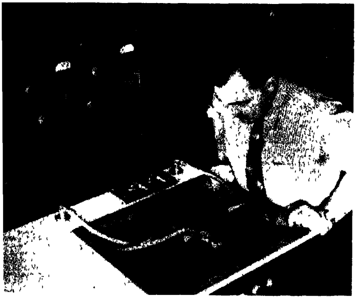
Induction heating has been an important factor in brazing operations. In one plant a brazing operation that took a highly skilled operator four minutes with a gas torch is now done by unskilled women operators in forty seconds using induction heating equipment. Inspection of the joints is unnecessary because of the uniformity provided by the electronic methods.

Hollow propeller blades for airplanes require a fillet of copper or copper alloy inside the leading and trailing edges. Welding on the outside edge is not sufficient to hold the two pieces together and is not possible along the inside edge. In electronic brazing, beads of brazing metal are laid along the inner edge and the propeller is moved edgewise through a coil to fuse the beads and bind the edges together. The same job done with a torch takes a longer time and requires more highly skilled operators. Greater warpage of the blades also results.

Oil well drill bits are toughened by a layer of tungsten carbide deposited on the teeth under high heat. This was formerly done with a gas torch by an operator who slowly and laboriously applied the carbide to each of



Coil springs are rapidly hardened to 55-80 Rockwell "C" hardness in a few minutes.



Operator checks automatically-timed induction heating and quenching of a small gear with a 15 kw electronic heater.

Dielectric heater is being "tuned" for correct frequency to properly laminate layers of wood at right temperatures.

the twenty teeth, one at a time. The whole bit can now be carbided in a few seconds by locating the tungsten carbide in position on the teeth, then placing the bit inside the coil of an electronic unit that heats the twenty teeth all at once. Unskilled operators do the work on semi-automatic equipment.

Like brazing, soldering is a high-speed production process with electronic heating During the war one terminal connector used in fighter planes contained thirty wire connections that required fifteen minutes when soldered one at a time with a hand iron The entire job was finally done in fifteen seconds by electronic induction heating

Quartz from Brazil is sliced into thin wafers for use in many radio transmitters as a means of frequency control In assembling the quartz crystal units, gas soldering often caused overheating and warping, or cracking of crystals With induction heating, this danger is entirely eliminated and six crystal units are soldered simultaneously by electronic means in three seconds Heat is produced only where it is needed at the joint area, and so rapidly that no harmful heat is conducted to the crystal

In the assembly of aircraft, rivets must often be driven in inaccessible locations To spread the end of the rivet inside the plane, a power charge is inserted in a recess at the end of the rivet The operator explodes the charge by applying heat to the rivet head with an electronic heating gun, and this spreads the end of the rivet (45).

Although many spectacular jobs have been done with electronic heating, it must be pointed out that it is not a general substitute for steam, gas, electric-arc and other older methods. The cost of electronic heat is admittedly higher than these methods and this factor must be considered in defining its applications If a special technique is required to do a faster, better or cleaner job, or if the job cannot be done by any other method, then electronic heat becomes economically feasible and practical

Electronic heating equipment is built to industrial standards and is available in both desk-size and rack-type cabinets. The units contain simple circuits and the parts employed are easily replaced by plant electricians. Maintenance chiefly involves the replacement of vacuum tubes and changing of fixtures and jigs used in applying the heat.

Welding

Spot welding, projection welding, pulsation welding and seam welding are some of the forms of electrical resistance welding in which two important factors, time and magnitude of current flow, can be controlled electronically by vacuum tube equipment to govern the quality of the weld (46, 47, 48, 49, 50). In such equipment, tubes called Ignitrons handle currents as high as several thousand amperes and interrupt such currents anywhere from 50 to 1200 times a minute without excessive maintenance.

Ignitrons and other electron tubes work together to form electronic resistance welding controls that automatically compensate for variations in line voltage and for the amount of metallic materials between the jaws of the welding machine. The welding of the tubes provides precision control of resistance welders that produce innumerable reliability records In one refrigerator plant, 21,000 evaporators containing 1,250,000 spot welds, 22 miles of gas-lit seam welding and 94 miles of intermittent seam welding were turned out without a single unit being rejected because of faulty welds

In some welding jobs an automatic electronic check of welds is made by a recorder (49) This is used in spot welding of bodies of aircraft, rail cars, automobiles, buses, trucks, and trailers, where there has been greatly increased use of welding for structural parts that are under pulsating stresses

Another type of welding in which the electronic tubes generate the actual power used for making the weld is high-frequency welding (51) In the aircraft industry it welds paper-thin sheet metal to metal structural parts, giving air-tight joints with full mechanical strength It welds threaded stud bolts to flat boiler plates, bolts of dissimilar metals end to end with no deformation whatsoever at the joint, metals such as magnesium that heretofore were unweldable, and handles a host of other difficult welding jobs

Precision spot welding of the heavier gage metals is quite common Relatively little attention has been given until recently to precision welding of light gage metal sheet and wire Spot welding of nickel, steel and aluminum wire only a few thousandths of an inch thick is now done by energy-stored spot welders (47) These machines utilize an electrical condenser having a capacitance of about 200 microfarads which stores the energy and releases it in one high-current discharge through the spot to be welded Heat developed by the tremendous current does the actual welding Electronic tubes in the machine do a double job, they rectify the output of a high-voltage transformer so that direct current is available for charging the condenser, and they act as a switch or control so that the condensed discharge takes place at the exact instant that is required to make the weld.

A similar arrangement of electronic equipment is used in the high-speed electronic flash units now widely used by photographers in the United States. In these, the condenser discharges through a gas-filled tube which emits a brilliant flash of light, much greater than that from the usual flash bulb The flash, however, takes place in a much shorter time interval, about 0002 of a second, so that moving objects and people can be "frozen" on the negative (52, 53)

Electronics in Prospecting and Mining

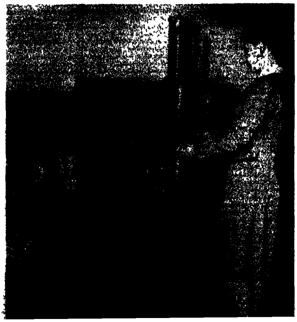
In the continual search for oil and mineral deposits, electronics is fast coming to play an important part in prospecting, in getting the material out of the ground and in refining it into usable form (54)

Vacuum tubes are especially important in connection with the reflection seismograph method of exploration being used so successfully in the hunt for new oil deposits, where they boost many times the feeble earth impulses resulting from the distant dynamite explosion, and also serve in radio equipment to transmit and record the instant of this explosion

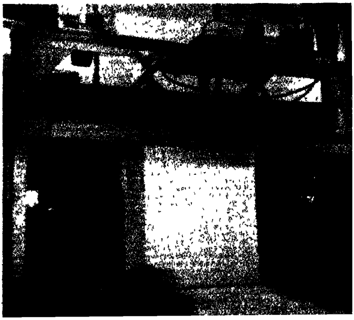
Electrical measurements made between stakes driven into the surface of the earth often call for electronic equipment to increase the sensitivity of the instruments. Electronic equipment plays just as important a role in talk-back systems used at the drilling rig for intelligible communication from a workman near the top of the derrick to the noisy derrick floor, providing coordination of effort in handling the heavy drill pipe

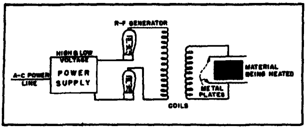
Electronic tubes are indispensable in the recently developed radioactive or gamma-ray method of logging oil wells This method is used to locate profitable oil-bearing levels in an existing well and to predict performance of wells to be drilled nearby. Electronic apparatus is also used in modern mud-logging techniques, in which the mud used as drilling fluid is continuously analyzed In another technique, this mud is inspected under strong ultraviolet illumination, under which cer-

Dielectric heating seals thermoplastic materials such as bathing caps that can be "sewed" together by R-F heat.

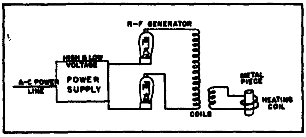


Electronic controls regulate cloth so that perfect register is achieved in printing.

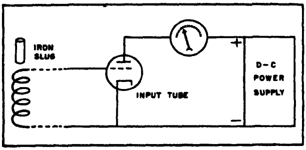




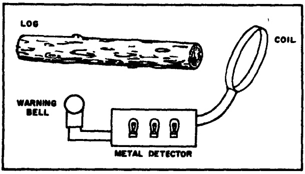
Essential portions of a dielectric heating machine. Electronic tubes generate R-F power to heat materials.



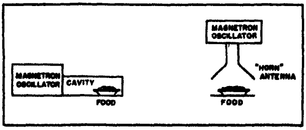
Electronic induction heating can be done by the same machine which does dielectric heating. Work piece is inserted inside turns of coil shown at right.



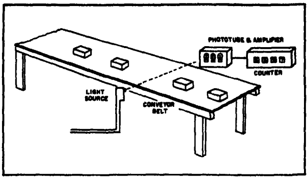
Basic circuit of an electronic measuring instrument. Flow of current is indicated on the meter. Here a strip of iron inserted in the coil produces the actuating voltage.



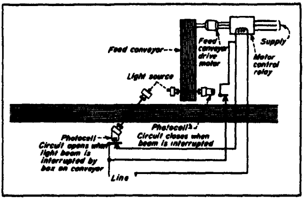
Log is passed through large coil to locate scrap metal embedded in it. Electronic equipment detects change in current and actuates an indicator such as a bell.



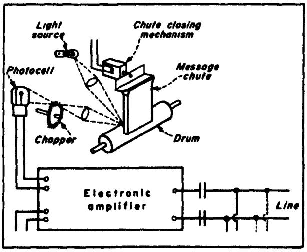
Two methods of heating precooked frozen food. At left, food dish is rotated in electric field inside the ultra-high frequency cavity. At right, more uniform heat is attained by means of a "horn" antenna which sprays radio waves at food.



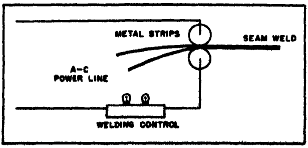
Phototubes change in electrical characteristic when illuminated. If light beam is interrupted, this change feeds an electronic amplifier, causing other machines to do such things as sort, count, spray, etc.


Feed conveyor
Feed conveyor drive motor
Supply
Motor control relay
Light source
Photocell
Circuit closes when beam is interrupted
Photocell
Circuit opens when light beam is interrupted by box on conveyor
Line

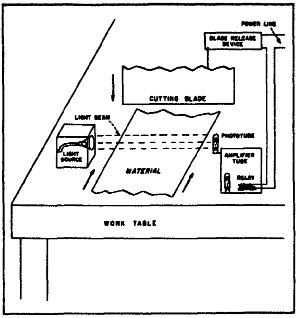
Photoelectric tubes control conveyor system. If box should start to transfer from feed conveyor to main conveyor, no other package could approach on main conveyor and jam system.



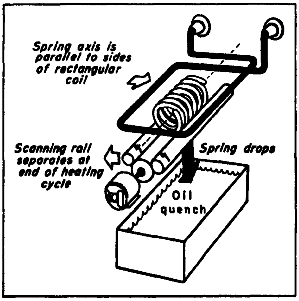
Messages can be reproduced by facsimile transmission. Message sheet is automatically wrapped around a drum and scanned by a light beam.



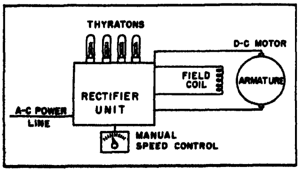
In resistance seam welding, electric current flows between strips passing between metal rollers, generating welding heat. Electronic tube interrupts current several hundred times a minute to produce a series of overlapping welds.



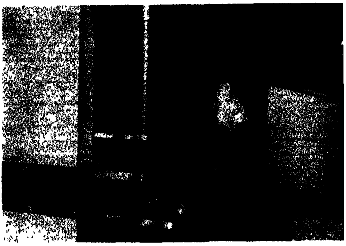
An example of a simple photoelectric safety device on a slicing machine. If worker's hand interrupts light beam on phototube, cutting blade can not fall.


Spring axis is parallel to sides of rectangular coil
Scanning roll separates at end of heating cycle
Spring drops
Oil quench

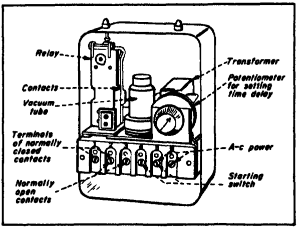
Simplified drawings showing principle of system devised to harden coil springs. Uniform heating is obtained by rotating the spring with two rollers, one of which drops the spring into an oil quench.



Elements of electronic motor control circuit. If control is electrically or mechanically connected to the load, automatic speed adjustment can be made as required.



Console model electron microscope has direct magnification range up to 20,000 times, with photographic enlargements up to 100,000 diameters.



Time delay relay circuit consists of a tube to serve as a switch, an adjustable resistance or potentiometer, condenser, transformer and resistors.

tain oil-bearing sands become highly fluorescent

Ultraviolet light from mercury-arc electronic lamps is used in hunting for mineral ores having fluorescent properties Scheelite is one example Several important deposits have been located by means of its characteristic fluorescent glow.

The geophone, an electronic device popularly known as the radio metal locator or "treasure finder", is widely used for locating conductive mineral deposits fairly near the earth's surface. A radio frequency oscillator is used to radiate energy into the earth When this energy encounters a sudden change in earth characteristics, the energy is reflected back upward or disturbing radiations are produced that can be detected with a locating instrument much like a radio receiver The operator carries the instrument over the ground while watching a meter or listening with headphones, and from the resulting indications can visualize the nature of the earth directly beneath him. Buried pipes, cables and metal objects of any kind can also be located with this equipment, in some instances even under water. Applications of this equipment include locating buried manhole covers, metal boxes used to protect underground gas and water valves, metal cross-ties of trolley rails, and electric wiring in walls

Mercury Arc Rectifiers

Most industrial plants in the United States are supplied by the utility companies with electric power in the form of alternating current This is a very efficient type of electrical power but in some processes, notably the electrolytic refining of aluminum and magnesium and mining, it is necessary to employ direct current The conversion of alternating current to direct current has been accomplished by motor-generator sets, but in the past few years many plants have installed mercury-arc rectifier tubes for this purpose These convert alternating current electronically and have no moving parts Use of this tube cuts losses about 40 per cent compared to other devices for changing alternating current to direct current

Electronic mercury arc power tubes vary in physical size from the smallest, 16 inches long, to the largest, 8 feet high Some are contained in a glass shell or envelope, while others have metal envelopes The internal construction is similar to the simpler type tubes contained in home radio receivers. They are particularly useful for operating railway cars, dumpers, cranes, elevators, and similar heavy machinery in mines and mills (11, 52).

Electronics, the magic word of many recent significant developments in industry, instrumentation and research, has proven to be a useful tool in many plants and shops Initially developed for communication purposes, the evacuated glass and metal envelopes are now recognized as having been successfully applied in many industries and have every indication of finding more jobs to be done.

Illustrations for this chapter were obtained through the courtesy of General Electric Co, Westinghouse Electric Corp, Monarch Machine Tool Co, Fairchild Engine & Airplane Corp, and Radio Corporation of America.

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CHAPTER X

FOOD PACKING

by T. L. SWENSON

Demands for processed as well as fresh foods in 1946 exceeded those of any previous year in history, and production in countries not devastated by World War II reached all-time highs Total production of canned foods in the United States for 1946 has been estimated at 646 million cases, exceeding the previous year's pack by about 80 million cases. Production of glass-packed foods was well maintained at about 280 million cases Frozen foods reached a peak of over 2 billion pounds packed (1)

As was expected, the wartime dehydration industries declined and returned to their approximate pre-war status, despite the fact that many important technological advances in dehydration were made, particularly in the drying of eggs and vegetables, but also in the dehydration of foods such as meat and dairy products It is generally apparent that World War II lent a great impetus to nutritional and food-technological investigations and vastly greater attention is being given now to healthfulness, sanitation, deteriorative processes, methods of preservation, and economy in production and distribution than was ever given in the past The technological investigations devoted to dehydration as a process have now been supplanted in large measure by attention to low-temperature preservation, freezing in particular. Food science, however, is concerned not only with processes but also with fundamental and basic factors in preservation and use of foods, and all processes (canning, freezing, dehydration and pickling) as well as fresh-product industries are in a true sense the benefactors.

The early months of the year 1947 witnessed some marketing difficulties that resulted from the large packs of 1946, particularly in frozen fruits and vegetables, but also in canned products of the same general class of foods Supplies in the United States were greater than markets could absorb, despite large domestic demand and the fact that exports were roughly five times those of pre-war years. (1)

Marketing troubles, particularly in frozen foods (2, 3), were usually explained as due in some degree to low quality and to the buying public's demand and ability to pay for the better grades of foods. There has been evidence, too, that per capita consumption of foods has increased in the United States, thus indicating not only public interest in better quality but also capacity to consume larger amounts than were previously considered as average and standard.

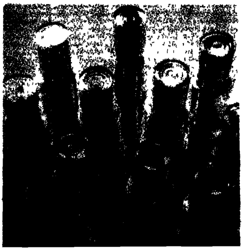
A generalization that seems applicable to the immediate post-war period, with which we are here concerned, is as follows: Reconversion and expansion of food manufacturing facilities have lagged behind expectations because of unprecedented high costs and labor shortages In war devastated countries the process of reconstruction will require an unpredictable period At the same time, technical and scientific knowledge related to nutrition and foods has increased. The war, moreover, has demonstrated the colossal and over-shadowing importance of abundant and good food to a sound world-wide economy

Immediately following the war, efforts were made to discover the new processes developed and used in the defeated enemy countries (4, 5, 6) and also to assemble for useful purposes facts developed in victorious countries (7, 8, 9, 10, 11, 12) The accumulation of information, scientific and technical, which is presented here only in part, falls far short of adequate use and application, largely because the expected and hoped-for period of post-war construction and development has only begun

Undoubtedly the most significant contribution of World War II to food research was one of moral advancement among research workers themselves. The war saw the teaming together of men from all fields of scientific endeavor, men who had never previously dreamed of working together. It can truthfully be said that we can look with just pride upon our technological advancement and our food production record.

THE INTERNATIONAL INDUSTRY YEARBOOK attempts to point out major trends and directions in the vast and scattered food industries of today Nearly every village has its food industries, and every home engages in some form of processing In metropolitan centers and regions of specialized and concentrated pro-

Today's metal containers are standardized in a simplified-practice list of 41 cans.



duction the food industries usually equal, and in some instances outrank, all others A major portion of the sum total of scientific endeavor is devoted to nutrition and foods Our purpose here is not only to describe briefly various technical developments but also to supply a guide to literature on trends in applications

Meats

The war stimulated research on the dehydration of meats by such methods as drying on drums and plates, vacuum drying, and cabinet drying Retort cooking, followed by grinding and drying, proved to be a rapid method The usual types of drying equipment were tried, but results were never sufficiently encouraging to justify large volume production (13, 14, 15) Efforts were made, as with other dried foods, to compress the dehydrated meat in order to save space and exclude air (16). As in other wartime investigations of food dehydration, the necessary objectives included ability of the product to withstand severe storage conditions. In studies of retention of nutritive values (17, 18, 19) it was found that original products, especially the proportion of fat, had much to do with keeping quality Retention of thiamine was found especially difficult, and in general the products were unstable at higher temperatures (above 70°F) It was demonstrated that good quality products could be obtained with the following limitations

(1) Meats were necessarily ground, (2) They required highly effective packaging (that is, gas packing to displace oxygen), (3) Quality retention was sensitive to high temperature in storage Extensive Army use of frozen and fresh carcass meat, and of canned meats in advance posts, made it unnecessary to continue the meat dehydration program beyond its initial stages

A great deal has been published on freezing and the freezing storage of meats, as well as on other foods, in recent years, and journals are publishing new reports of technical studies regularly Through research of the State Agricultural Experiment Stations, there has been constant effort to meet demands for information on improved methods in locker plants, which have been increasing in number steadily during the past fifteen years

The U. S. Department of Agriculture and most of the State Agricultural Experimental Stations have issued bulletins and circulars on the freezing of meat (20, 21, 22). In the United States the number of locker plants now approximates 8,000 and for the most part locker plant patrons use their storage space for meats and poultry Thus about four million families or between fifteen and twenty million people are consuming locker-stored meats. A conspicuous development has been the addition of slaughtering and packaging facilities and services in a large number of locker plants The main trends have been toward use of (1) lower temperature for storage (0°F or lower); (2) more effective packaging (foils, glass jars, wraps or bags made of material containing rubber hydrochloride), instead of ordinary papers or cartons; and (3) faster freezing (made possible by special freezing rooms in many plants).

The situation with regard to commercial retail sale of frozen meats is, however, entirely different Much has been written and said about the possibility and probability of this virtually revolutionary development and, as a natural result, large meat packers and others are conducting various types of studies (23, 24, 25, 26, 27), the overall objective of which is to preserve meats in essentially *fresh-quality status* and to prepare and freeze processed meat products with the retention of the highest nutritive values and consumer acceptance

Conspicuous among the technical problems are those of rancidity and related chemical changes Physical changes, however, may be even more important, since freezing necessarily involves crystallization of moisture with subsequent surface effects that must be adequately controlled, especially in the small consumer-sized package The customary aging of meats in coolers may not be an advantage in frozen cuts since fresh flavor may be lost Freezing increases tenderness, therefore aging in coolers would not be necessary for that purpose Inclusion of salt in frozen meat products is apparently detrimental Numerous other problems in this particular field require investigation before any large-scale trial of commercial retailing of frozen meats is attempted The obvious advantages (retention of bone and other wastes at the slaughtering plant, resulting in savings in transport and storage costs) must be offset against enormous problems of equipment and personnel Only one retail store in fifteen has any reasonable capacity or kind of low-temperature display cabinet at present This fact alone should suggest the ultimate magnitude of changes within the retail trade

Meanwhile, studies directed toward improvement of smoked meats (28, 29) continue, and new canned meat products, such as baby foods and foods for the aged, as well as for pets, are being developed and are finding markets Evidence has accumulated (30) suggesting the value of cool storage for canned meats, as well as other foods A number of research workers have demonstrated the ill effects (darkening, loss of the less stable vitamins, and the development of off flavors) that result from exposure of various canned products to warm temperatures Cool storage involves increased costs, but it may be assumed that as air conditioning in plants, storages, and wholesale and retail establishments develops, there will be increased use of such space for canned products. Improved canned products would, of course, increase their competitive advantage as compared with frozen processed meat products.

Cereals and Baking

The most talked-of recent advance in baking is that of frozen dough, for use in pies and other prepared frozen dishes. Volume is small, but interest is maintained primarily because of novelty and also because of experimental demand (as in air travel) for precooked frozen foods and whole meals. A well publicized bake shop specializing in frozen dough in Oak Park, Illinois, (31) has no ovens and does no baking. Similarly, in frozen food markets elsewhere frozen doughs are under trial and frozen pies are reported to enjoy reasonable consumer acceptance.

Cereal chemists in a few of the State Agricultural Experiment Stations and in laboratories of the larger milling companies are continuing basic studies on composition and behaviour of the components of wheat and other grains The value of the food and milling technologist and the laboratory in the milling and baking plant, as in other food plants, is coming to be more fully recognized, not only for purposes of inspection and quality control as applied to raw products, but also as a means of developing finished products of the highest quality (32, 33, 34, 35). Studies of new processes (as yet commercially undeveloped) continue to be made, for example, on peanut flour (36), vacuum processing of rice (37), high-frequency heat in baking (38), and a new process for removal of bran (39).

Eggs and Poultry

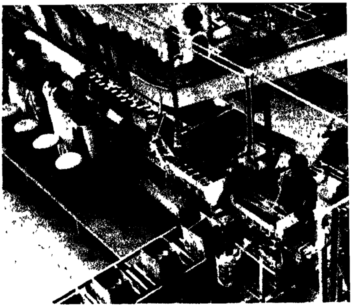
A problem of long standing in fresh egg storage is loss of quality prior to receipt of eggs in egg storage warehouses Cleaning and oiling (40) and thermostabilization (41) have been demonstrably successful when applied under competent technical supervision The universal adoption of methods developed has been retarded by the lack of trained technologists Individual farmers (particularly on farms where poultry is a sideline) cannot do this work uniformly and consistently Only fresh eggs from healthy flocks should be used for any food purposes, hence the achievement of a better supply seems to be a marketing problem, involving closer relationship between producer and packer

Dehydrated eggs were one of the chief food problems of World War II Large expansion in production of dried egg reflected the fact that dehydration was about the only method whereby large volumes of egg could be moved to the armed forces and to the Allied countries It was not until late in the war years, however, that it was possible to produce adequately stable, good-quality whole egg powder Practically the same factors hindered the dried egg industry as hindered dried vegetables These factors were the necessity for very low moisture content and for reduction of oxidation and other chemical changes through gas packing Enzymic oxidation, which affects dried vegetables and fruits, apparently does not affect eggs

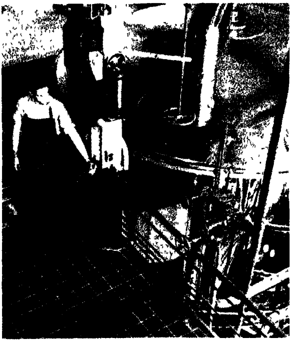
It is now possible to produce good-quality dried egg (42, 43, 44, 45, 46, 47, 48, 49). Slight acidification contributes to keeping quality of dried egg and may become a commercial practice with or without the addition of sugar. Excellent original quality, strict sanitation, and close adherence to requirements with regard to moisture content and packaging are, however, necessary.

Decline in production of dried egg powder has been accompanied by an increase in frozen egg production With frozen egg, as with egg powder, there is a need for concern about bacterial content, particularly salmonella species (50, 51). Operational problems being studied include freezing methods and rates, effects of freezing storage on usefulness, and method of defrosting (52).

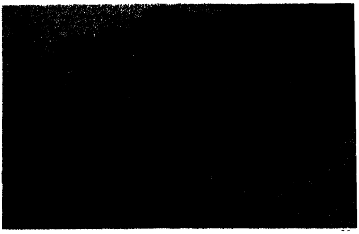
Frozen eviscerated poultry packed cut up for frying or whole for roasting is in effect serving as an experiment in retail sale of frozen meat in consumer packages. Similarly, frozen fish have been, in a sense, a



Modern materials handling and packaging equipment promote efficiency in this pineapple canning plant.



Materials of construction, such as Monel and pure nickel, maintain product purity in this brewery.



Improved design of equipment in various freezing units have contributed much to food industry progress.

Automatic filleting machine recently developed for continuous processing of haddock, cod and similar types of fish; heads are first cut off before the fish is automatically scaled, cleaned and filleted.

preliminary and also successful experiment A number of large packers have apparently succeeded in their frozen eviscerated poultry operations, and it seems likely that this product will expand to large volume as facilities for retail sale of frozen foods develop The trend away from marketing of freshly killed "New York dressed" and live poultry toward packing and storage may soon develop at an accelerated rate, as a result of the impetus given by freezing technology Turkeys are becoming a year-round rather than a strictly seasonal commodity. Probably the poultry processing plant of the future will conduct both canning and freezing operations in order to extend and vary its line of products Among precooked frozen foods, chicken a la king has established its position as one of the most successful. Of the technical problems in poultry packing, sanitation, avoidance of visceral taint, and quick handling from slaughter to storage are most frequently discussed Recent evidence indicates that poultry to be frozen, like meats, is better if the precooling step is omitted. Freezing in itself tenderizes the meats. Fresh flavor is best preserved by rapid handling and also by sub-zero storage temperature, particularly if the product is to be held longer than two or three months (53 to 58).

Fish

The fishing industries have regarded the advent of freezing as their golden opportunity to expand marketing in regions remote from seaboards. As freezing technology has developed, frozen fish products have increased in number and quality. Recent developments in freezing have involved consumer packaging and retail sale (59, 60, 61, 62, 63). The most important problem is probably that of storage of frozen fish in the vicinity of other foods. Freshly caught fish, processed before decline of rigor mortis, are actually inoffensive in odor. If thoroughly frozen and adequately packaged, it would therefore seem possible to store fish with or near other foods Recently the first fishing craft with complete processing and freezing equipment have put to sea and, if these ventures prove successful, they may stimulate further attention to the industry's major problem, which is ability to handle the product with minimum elapsed time between catching and processing Shrimp, one of the most valuable as well as most difficult of sea foods to handle, would undoubtedly be benefited as an industry by freezing shortly after capture (64, 65) As in other food industries, there is interest in frozen precooked fish products (66); thus it seems probable that the fish packer of the future will use low temperature (including freezing) for more purposes than in the past, and that he will produce a wider variety of finished products.

Dairy Products

The two recent major industrial developments that have affected most food commodities (namely, wartime dehydration and pre- and post-war freezing) have not markedly affected the dairy products industries. Ice cream still outranks all other commercial frozen foods in volume. Powdered milks are well known in industry, and during the war studies of their compressibility were made (67) Frozen concentrated milk in small containers, to be consumed after being defrosted, has proved feasible and may find use, for instance, on ships. Both butter and cheese can be dehydrated or frozen without harmful effect. Recent trends in butter storage are toward lower temperatures than were previously used. Butter is now commonly stored at 0°-10°F., and some technologists recommend sub-zero temperatures.

Despite the minor importance of dehydration and freezing in recent dairy science, there is no dearth of investigative literature. A recent collection of abstracts of papers on milk published in 1946 includes 370 titles (68). Subjects that indicate the nature of present-day dairy research are deaeration and its effects on vitamins and flavors of milk (69), stabilization of cream (70), heat treatment for butter (71), continuous methods of butter production (72), use of frozen curds in making cheese (73) There has been some interest in proper temperatures for the curing of cheese (74), and pasteurized milk is now recommended for cheese manufacture Shortage of sugar caused some problems in the storage of sweetened condensed milk during the years of sugar shortage, and the question whether cool storage would be advisable for all condensed and evaporated milk is being considered

Vegetables

A detailed report on wartime vegetable dehydration and the efforts of research and industrial agencies to improve and perfect dried vegetable products would require many pages Probably the whole large effort can be summed up as follows· Large quantities were produced and used, and the supply problems due to shortages of tin and steel for cans and also shortage of shipping space were relieved Problems of deterioration, however, persisted, and the general course of research revealed that these problems could be solved only by such measures as (1) further reductions in moisture beyond those easily obtainable in existing equipment, (2) applications of bisulfite solutions with some vegetables to control darkening, and (3) packing in carbon dioxide or nitrogen in order to reduce oxidation It was necessary that wartime dehydration products undergo severe storage and handling conditions, such as long-term stockpiling and often high temperatures and humidities These requirements imposed stringent standards in production

A general manual for processors of dehydrated vegetables and fruits (particularly the farmer) was published in 1944 by the U S Department of Agriculture (75) A number of State Agricultural Experiment Stations also issued advice and conducted studies, and in England a planned program was undertaken (76) At the end of the war, when government contracts were largely reduced or canceled, research was still under way. It is unquestionably true that superior products can be manufactured now, as compared with those available at the beginning of the war A new and stable vegetable dehydration industry would, however, require improved equipment and definite peacetime marketing advantages. Of the vegetables, white potatoes now seem most suitable for development as a new dehydrated product.

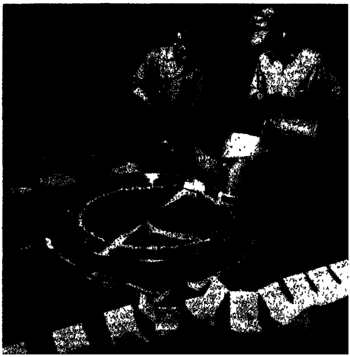
A major concern in vegetable dehydration was the necessity for inactivation of enzymes in the cut vegetables by steam or hot water blanching or by treatment with bisulfite. A noteworthy exception is onions, which require no blanching and have been a stable dried product commercially for many years. Blanching was closely related to government purchase specifications, and adequacy of blanching was determined by tests for enzyme activity. Research workers found continued difficulty in distinguishing and measuring the effects of latent enzyme activity, moisture content, and oxygen in the container. The best products, so far as keeping quality is concerned, are those with the lowest moisture content and least oxygen in the container. Potatoes (77, 78, 79, 80, 81, 82) were the most important dehydrated vegetable and were the most extensively studied Sweet potatoes were also important (83, 84, 85), but not much more so than carrots, cabbage, and beets Other vegetables were studied to some extent and also soups (86, 87, 88, 89, 90).

The benefits of food technology of the vegetable dehydration program lie in the sound knowledge obtained on processing requirements and on the nature of the deterioration in vegetable products than may occur if processing requirements are not met

Commercial freezing of vegetables, begun about 1930, has advanced in step with the commercial freezing of fruits It is evident now, however, that superior quality (the fresh, pronounced flavors and colors and excellent retention of nutritive factors), so much talked of earlier, must be *abundantly* present if the industry is to gain ground as rapidly as in its early stages One problem of importance, particularly with peas (the most important frozen vegetable), and also with lima beans, is the acquisition and grading of the raw product (91, 92, 93, 94) Freezing does not make the product uniform, as canning tends to do The product must be uniform and excellent when it is harvested This requirement places added responsibility on the producer and, in fact, many of the more successful processors of frozen vegetables are actually engaged in farming

One of the frozen food journals is attempting in a series of articles, each on a single product (95, 96, 97), to cover all steps in frozen vegetable (and also fruit) production from seed selection to retail sale The book by Tressler and Evers (9) encompasses the subject of freezing technology in an excellent manner The Western Regional Research Laboratory of the U S Department of Agriculture has attempted to list technical pub-

Volumetric filler turns out 100 cartons of beans per min.; cartons are automatically closed and sealed.



lications on fruit and vegetable freezing (126) One of the important processing problems is blanching to inactivate enzymes (98, 99, 100, 101, 102, 103) The extraordinary attention paid to this problem, as evidenced by the number of publications, is largely due to efforts to find an objective test for adequacy of blanching Other problems are those related to specific vegetables, some of which, for one reason or another, are not well adapted to freezing Methods of freezing (104) have been considered, and fast freezing is gaining preference for no apparent better reason than economy in use of equipment Packaging trend is toward those materials with greater resistance to moisture vapor, such as metal foils, and adoption of the hermetically sealed can or jar may be in the offing.

Leaders in the industry have discussed the future of frozen vegetables and other foods quite seriously during the recent months of marketing difficulties, and for the most part have reaffirmed their conviction that slow growth based on really distinguished quality is the only sound "philosophy" for the future

In the vegetable canning industry the increase in packs of juices has been a noteworthy development Canners are concerned with such problems as vitamin retention (104), testing raw products for maturity (105, 106), other quality factors (107), and new products such as mung bean sprouts (108) In the Pacific Northwest some canners have adopted a froth-flotation method for the removal of nightshade berries from canning peas (109, 110)

During the war years there was interest in brining of vegetables as an alternative to dehydration (111, 112), particularly as a household measure

Producers of fresh vegetables, shippers, and associations of producers and shippers are aware that improved practices will hold their markets, protect them against increased selling of processors, and enlarge their share of the consumers' dollar Particularly in southern and southwestern regions of the United States, but also in northern regions of large production, there is interest in prepackaging of fresh vegetables (and also other products) in consumer-sized units with refrigerated handling all the way to market Improvements in packaging materials and machinery in refrigerated transport and in distribution and retail equipment seem to offer promise of progress in this direction Savings in lowered shipping costs and from reduction in wastes must offset the increased costs of packaging and handling (113, 114, 115). There is continued interest in new chemical preventives of deterioration in fresh products, one of the most recent being the methyl ester of naphthalene acetic acid for control of sprout growth in potatoes (116) It is still undergoing trials.

Fruits

It was anticipated by some observers that the fruit-dehydration industry would gain some new and improved technology from wartime investigations in the drying of vegetables. Fruit dehydration (both sun drying and mechanical drying) is, however, a well established industry and the techniques have not undergone major changes recently There is constant effort toward improvement and there is interest in such matters as steam blanching in addition to, or in place of, sulfuring and in better handling generally (117, 118, 119) Interest was created during the war in foods processed from dehydrated fruits such as bars and spreads (120). Reprocessed dried apples, ground and dried further, were produced and gained ready acceptance More recent tests have shown that most dried fruits are better if stored at temperatures lower than room temperature and with moderate to low humidity Cold storage offers protection against changes in color and flavor, sugaring, and development of insect infestation

There was lively interest in the possibility of producing fruit and also vegetable powders during the war and that interest has continued The problem of obtaining a free-flowing stable powder in commercial equipment has not been completely solved, although better understanding of the nature of the problem has been gained (121, 122, 123, 124, 125) Some of the processes investigated have involved vacuum concentration and other methods, in addition to spray drying, and final products have varied from flakes to powders to thick concentrates It seems unlikely, from research on dried cubed vegetables and egg powders, that a product can be made that will tolerate exposure to air and higher temperatures

Fruit freezing investigations have created a substantial body of technical and semi-technical reports (126, see also 9) As with vegetables, a fundamental problem is the pre-treatment to control discoloration and other types of deterioration Whereas scalding or blanching is the rule for vegetables, the same treatment, or as an alternative, treatment with sulfurous acid, bisulfite solution, ascorbic acid, or ascorbic and citric acid is common with fruits Each of these methods is under investigation, singly or in combination with others (126, 127, 128, 129, 130, 131) Ascorbic acid has received the most attention recently, since it is a valuable nutritive substance (vitamin C) as well as an effective antioxidant The addition of calcium chloride to the dipping bath for apples has resulted in firmer texture for both frozen and canned product (132), and this method may result in increased use of varieties like McIntosh and Delicious, which are naturally soft, in the pie trade.

There are many reports of experimental work with varieties and methods. State Agricultural Experiment Stations in areas of heavy fruit production, such as California (133, 134, 135), Washington, New York, Michigan, Louisiana (136), and others, have reported results Studies on vitamin retention (137) are less frequently engaged in, because the general fact of excellent vitamin protection in good-quality, well handled frozen products is widely recognized. Frozen food processors, firmly aware now that they must specialize in individual crops to the extent of controlling production from the seed and soil stages on through harvest, processing and sale, have become interested in complete individual crop information (138).

It is fairly easy to account for the intense and widespread interest in frozen juices, frozen concentrated juices, frozen purees, and in products made from these materials, such as jams and jellies. One reason is the marked success of canned juices, particularly juices of tomato and grapefruit, which are good sources of vitamin C Another is the important economic factor of waste utilization, juices and purees can be made from lower grades of fruit Still another is the fact that some of these products find a ready market in the jam and jelly, baked-goods, and ice cream trades

The usual problems of quality, pretreatment, sanitation, speed, freezing method, packaging and storage face the packer of juices and purees In addition he must deaerate the product or avoid the incorporation of air, and must protect the "fresh" flavor by use of as little heat processing as possible (139, 140, 141, 142, 143, 144, 145, 146, 147) Excellent frozen fruit purees and products of puree can be made, but the process requires rigid, painstaking control Increase in volume is dependent on progress in the application of closely controlled technique

Canning remains the large-volume method of preserving fruits, fruit juices, and purees and jams There is no definite trend toward decline in glass packing from its wartime peak, and there has been no clear-cut demonstration of significant superiority of either glass or tinned containers for heat-sterilized foods Such measures as use of ascorbic acid to enrich the product and reduce oxidation discoloration, and calcium chloride dipping solution to firm the texture, are applicable in canning as well as freezing (148, 149, 150, 151, 152, 153, 154, 155, 156) Clarification (154) and avoidance of sediment (149) are easily achieved in canned juices. Although no conclusive evidence is available in the technical literature, it seems possible and perhaps highly probable that frozen food packers will use cans in the future and that the canning trade may make use of lower temperatures in the storage and handling of their products

Advances in the Food Industry

Many observers have predicted a gradual merging or closer association of the two processes in actual industrial operation A comprehensive view reveals that canned orange juice, as one example (157), is protected against change when stored at 40°F., that some freezers are beginning to use cans, that refrigerated transport, storage, and retail facilities are increasing and being improved, that air conditioning in retail and wholesale establishments is arriving; that canned milk and meat products have been protected from loss by freezing—in short, although the conclusion is still speculative, the industrial demarcation between low temperature and heat sterilization as protectives is disappearing This comprehensive view suggests immediately, of course, that a great deal of research is necessary in order to determine for each product the optimum conditions for optimum quality.

In the fresh fruit industry there is less interest in prepackaging in consumer units than in the fresh vegetable industry, but it is expected that retailers who handle vegetables thus prepared would also want fruits similarly packaged for display. As a result of increasing use of sound practices in apple storage, fresh apples are available in all months, and apple growers are constantly striving toward better methods Circulation of air through canisters of activated carbon (158) offers promise as a method of removing odors, ethylene, and the "scald gases" that cause apple scald The use of "hormone" sprays to control harvest dropping has resulted in some storage trouble, but it can be avoided by carefully planned harvesting and marketing The greatest single difficulty recently has been excessive bruising which lends added interest to new packaging ideas

Citrus growers would find an advantage in better methods of storage (159) to prolong the market season for fresh products, and it is possible that control of gaseous emanations will eventually prove helpful, along with surface treatments and packaging Hydrocooling (160) may find greater application, it is, essentially, washing in ice water and like many other methods applicable if sufficient advantage can be found to justify added cost

Olives are the chief fruit packed by pickling (161, 162) Advances recently in olive packing, the nut industry, and in tropical fruits such as bananas (163) have consisted principally of "streamlining"—that is, improved machinery and handling equipment to offset rising labor costs

Frozen Precooked Foods

Freezing technology has encouraged the belief that frozen precooked foods, practically ready to serve, can develop a large market, much larger than has been achieved by ready-to-serve canned or dried foods, such as soups It is a conservative estimate to say that hundreds of recipes for cooked dishes have been subjected to freezing in the hope that hotel fare could be brought conveniently into homes, restaurants, dining cars, airplanes and steamships Initial failures, of which there have been many, do not preclude eventual success. Problems of deterioration, especially rancidification and bacterial contamination (164, 165), and also problems such as freezing method and rate, reheating, packaging, defrosting and loss of aroma and flavors (166, 167, 168) have risen to plague those who have felt too confidently that the freezing method is fool-proof Frozen pies, according to recent comment, are succeeding, along with several others, for example, chicken a la king Frozen precooked foods are being used to some extent on airliners A great deal of research will be necessary (169), however, because each food will probably prove to have special requirements

Gelling and Sweetening Agents

The recent technical reports on pectin are numerous (170, 171, 172, 173, 174), and they reflect the fact that the market for gelling and thickening agents is large, both presently and potentially Other products of a related nature are starch (175, 176, 177), gelatin and glycerine (178) It seems possible that low-methoxyl pectin (174) will become more important because of its ability to form stable gels with low concentrations of sugar Partially de-esterified pectin must, however, be produced at low enough cost to become competitive with other gelling agents, and present methods are costly.

Wartime shortage of sugar has stimulated interest in new sweeteners (179, 180, 181, 182), and in methods of processing that reduce sugar requirements Enzyme converted corn syrup has been recommended as a sweetener, with apparent success, in frozen foods, however, its general use in this connection is an open question and one that is presently receiving considerable attention.

Packaging

The subject of packaging, if judged by the number of articles published, is one of the most important in food technology Wraps and packages serve many purposes—from protection of apples against "scald gases" to advertising of brand. Packers of many foods have striven for novelty in colors, shapes, closures and other features Consumers sometimes criticize (183) and technologists urge further study (184, 185, 186, 187, 188), especially in the direction of functional characteristics. One writer has pointed out that wartime packaging (189) has set standards of effectiveness that might well be followed Undoubtedly the important position given currently to packaging is due to several factors—the new dehydrated and frozen foods, especially the war and its demonstration of the value of good functional packaging, mounting costs and the new mechanical handling that centers attention on the pallet load as a unit.

Dehydrated foods (190, 191, 192, 193, 194) have required that attention be given to effective sealing, removal of air, and replacement of air with the so-called inert gases, nitrogen or carbon dioxide In effect these requirements have demanded good-quality cans Packages of less rigid effectiveness have not proved acceptable for dehydrated foods In a sense this type of packaging is a logical final step in processing, just as the hermetic seal is one of the final processing steps in canning In wartime dehydration there were some attempts to avoid this requirement, but always at a sacrifice of product quality.

In the brief history of frozen foods there is evidence of growing realization that packages cannot fall short of doing the utmost possible to protect the product. Two reasons why frozen food packers do not use cans or glass are (a) the desire to show a marked difference between heat processed and frozen foods, and (b) the danger that canned or glass packed frozen foods might be allowed to thaw and spoil as a result of confusion with heat-processed foods Although frozen foods are not known to have been involved in any case of poisoning by the toxin of *Clostridium botulism* (195) the fear that canned frozen foods might lead to such difficulties has been a compelling deterrent to the use of cans.

Glass jars are extensively used by frozen food locker patrons who pack chiefly their home-grown produce. Commercial packers, however, have used a wide variety of materials, ranging from waxed paper, cardboards, laminated sheets, glassines and various cellophanes to rubber Hydrochloride films, foils, and wax dip coatings The functional standards set up by technologists have shown that excellent packaging means impermeability to moisture vapor at sub-zero temperature, as much exclusion of air from the package as possible, resistance to damage, ease of handling, and adaptability to mechanical filling (196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213). Another "must" in packaging is ability to carry the brand name and labeling data attractively It would seem apparent that careful consideration of materials and functional standards leads directly toward the tin-plate sealed can or the sealed glass jar There are, however, other effective and attractive packaging materials, and it seems only reasonable at present to say that packaging is one of the changing phases of a rapidly moving and comparatively new food processing industry

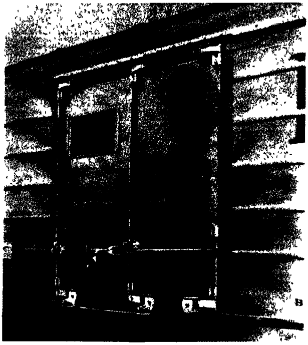
Packaging in processing industries other than freezing is a matter of perhaps minor concern, other processors are, of course, adopting some of the newer non-rigid materials (214) Finding the most appropriate packaging material for prepackaged vegetables and fruits is, however, proving to be a major problem (215, 216). This problem differs from that of frozen food packaging in one important aspect—the fresh vegetable and fruit is a living, respiring substance The package must be adapted to this characteristic of the fresh product, and it must meet other requirements, particularly it must permit mechanical application

The rapid trend toward mechanized handling has shown a need for better bulk packages, better cases and crates and greater uniformity in sizes and shapes Breakdown of crates and cases is a source of severe losses, and it is anticipated that full development of pallet and lift truck handling, with its savings in labor costs, will provide economic justification for better bulk packaging

Sanitation

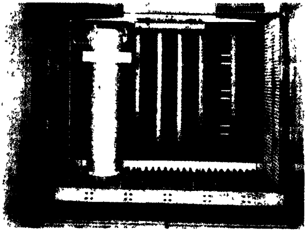
The constant striving of food industries toward control of health hazards and toward improvement in quality through sanitation and reduction of contamination is evidenced by the large stream of technical literature Each year's studies and commentaries cover such subjects as surveys of foods being consumed (217), governmental sanitary codes (218), methods of making routine sanitary investigations (219), water supply (220), and new detergents and disinfectants (221, 222).

Generally, it has been expected that post-war reconstruction and development would offer opportunity for improvements in sanitation Undoubtedly the experiences of war food production revealed opportunities for improved sanitation and called attention to laxities in practice Sharpened interest in economy has also led processors and handlers to re-evaluate some of their sanitary practices and estimate their effectiveness New detergents are available and also new sanitizers Of the latter, the quaternary ammonium compounds have aroused most interest (222) because of their effectiveness in combatting spoilage organisms and also their "residual effect"—that is, their ability to protect a surface during more than a brief period. Ultra-violet light and gylcol vapors are being considered for use in food establishments as means of disinfecting atmosphere, and their practical effectiveness being tested and discussed. Similarly, the use of ozone is being debated; ozone is recognized particularly as a fungicide, but health codes



Advances in refrigerated car transportation include improved door seals to help insulate car's interior.

Bunkers at both ends of car employ raised platforms for improving air circulation and for holding ice.



Cylinder in ice bunker contains dry ice; stainless steel car is light in weight and corrosion resistant.

Melons are loaded in cars and covered with a blanket of snow; they reach market in perfect condition.

Silicone film on surface of pans permits easy removal of baked goods for as many as 200 bakings.

Flavor is improved when Pliofilm sack separates barbecue sauce from weiners until ready for use.

restrict the concentration because of hazard to workers Sanitation, as a matter of course, requires constant educational effort and those who discuss the subject publicly usually emphasize regular and persistant "house cleaning" with attention to a rigid and effective schedule

New recent research has included studies of preservatives (223, 224, 225, 226, 227), although few preservatives are permitted, and new ones must undergo thorough consideration by Federal authorities before permission for use is granted. Certain pathogenic organisms continue to be studied (228, 229, 230, 231, 232, 233). Staphylococcus food poisoning is at present a matter of special concern, and will be investigated thoroughly Salmonella infection in eggs (42 and others) is also being studied, particularly to determine the extent of survival of the pathogens in dried and frozen egg products.

Within industries, and within plants, bacteriologists and sanitarians have made many studies—on frozen foods (234, 235), dried prunes (236), fruit juices (237), poultry, wine, and others (238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261)

In the field of insect control, the most important development has been the application of DDT (dichlorodiphenyltrichloroethane), which has gained wide recognition as an effective insecticide New insecticides are being sought, however, in order to avoid the mild toxicity of DDT and to destroy certain insects against which it is ineffective New rodent control products are also being developed, for example, Autu, a proprietary product recently admitted to use in food plants by the U S Food and Drug Administration (262 to 264)

Wastes and By-products

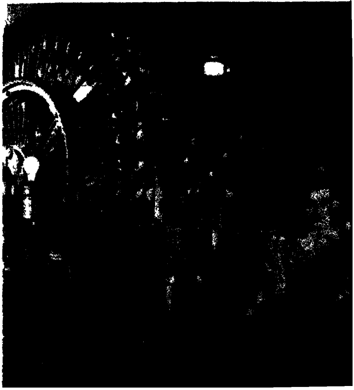
Disposal of wastes has continued to be a burdensome and expensive task in food processing plants, particularly in fruit and vegetable plants, because wastes there are voluminous (265, 266) An important phase of the value of any byproduct industry is its avoidance of cost of disposal Disposal in streams, the least expensive method, results in pollution of the stream and thus creates problems. Use of lagoons for liquids and various methods of spreading solid wastes on land are costly and a constant nuisance Salting and pickling plants present special problems, because salt contaminates streams, wells, and soils (267).

For vegetable wastes—that is, wastes that are not too sloppy—drying for use in feeds is a possibility, and some wastes such as pea vines can be ensiled. These dried products properly handled yield feeds of high nutritive value, and undoubtedly the full values of such feeds have not been utilized (268, 269, 270, 271).

Recent years have witnessed intensive interest in by-products from wastes and low-grade raw products. Four regional research laboratories created by an Act of the United States Congress in 1938 are devoting considerable attention to such objectives (272). Among new by-products under consideration or actual production are apple syrup (273), apple essence (274), syrups from grapes and raisins (275), yeast from pear canning wastes, molasses and other high-sugar-content wastes (276, 277), tartrates and grape wastes (278, 279, 280, 281), and bacteriological media from asparagus juice (282, 283). New culture media and factors in culture media have contributed conspicuously to the growth of the antibiotics industry Most important development of this sort has been the introduction of corn steep liquor (an agricultural waste product obtained from the wet milling of corn) into media for the growth of *Penicillium notatum*, which produces penicillin (284)

Some fruit wastes can be dried, like vegetable wastes mentioned above, as stock feeds (285). Purees and juices of fruits (mentioned under Fruits) constitute an outlet for low-grade fruits with large opportunity for development Low-methoxyl pectin (also previously mentioned) promises greater usefulness for apple and citrus wastes By-products of cereal crops of recent development include furfural from hulls of grain and corn cobs Soft grit for use in cleaning machine parts, made from corn cobs and grain hulls, and alcohol for fuel and other uses are among several possibilities from grain wastes A general summary of research on wastes in the U S Department of Agriculture is available in the annual reports of the Bureau of Agricultural and Industrial Chemistry and in the Yearbook of the Department for 1947 (286, 287). Much of this research is basically chemical and microbiological in character and is yielding considerable new information on sources of valuable materials and chemical compounds Development of industrial uses does not necessarily follow quickly, and may not follow at all, because of economic factors The investigation is, however, necessary in each case in order to lay the groundwork for ultimate solution of the problems

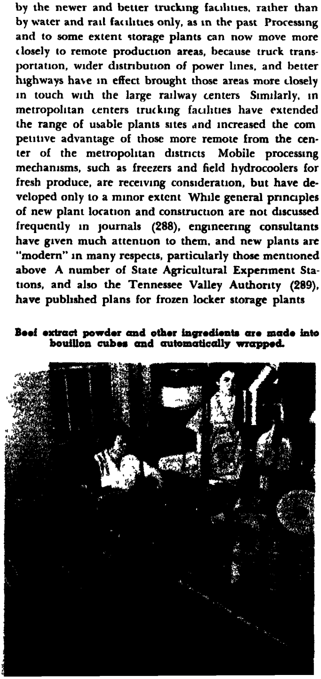
Metal cans are tested with air pressure before use; those with leaks or other defects are discarded.



Plants, Mechanical Equipment, Testing Devices and Methods

Plans and ideas for the construction of the wholly new or the remodeled plant appear infrequently in technical and trade journals. The subject is one of importance, however, because new developments are taking place The question whether to build a multi-storied or one-floor plant or storage is affected by new methods of mechanical handling Fork-lift trucks and pallets have given the one-floor plant, with high ceilings for storage space, distinct advantages, which are offset only by high value of land in certain locations New plants will make sanitization much simpler, through application of new sanitary engineering principles in construction Increasing use of air conditioning and refrigeration has centered attention on construction of walls, ceilings, and floors in which adequate insulation (287a) and moisture barrier will be provided The location of plants is affected by the newer and better trucking facilities, rather than by water and rail facilities only, as in the past Processing and to some extent storage plants can now move more closely to remote production areas, because truck transportation, wider distribution of power lines, and better highways have in effect brought those areas more closely in touch with the large railway centers Similarly, in metropolitan centers trucking facilities have extended the range of usable plants sites and increased the competitive advantage of those more remote from the center of the metropolitan districts Mobile processing mechanisms, such as freezers and field hydrocoolers for fresh produce, are receiving consideration, but have developed only to a minor extent While general principles of new plant location and construction are not discussed frequently in journals (288), engineering consultants have given much attention to them, and new plants are "modern" in many respects, particularly those mentioned above A number of State Agricultural Experiment Stations, and also the Tennessee Valley Authority (289), have published plans for frozen locker storage plants

Beef extract powder and other ingredients are made into bouillon cubes and automatically wrapped.



Plans for buildings and equipment, with flow diagrams, for vegetable dehydration plants of various capacities were made available during the war by the U S. Department of Agriculture (75) Additional designs for equipment and data on dehydration rates for vegetables (290) to be used in design of equipment are available at the Department's Western Regional Research Laboratory (Albany, California) on request. Information on dehydration techniques and equipment from other sources is also available (291, 292, 293, 294, 295), particularly on equipment or methods other than the commonly used tunnel and cabinet dehydrators.

Systems of freezing vary considerably (296, 297, 298, 299, 300, 301), although there are only three main types, distinguished by medium through which heat is removed—that is, by contact of the product with air, metal, or liquid The next few years will undoubtedly produce much new research directed toward elucidation and evaluation of principles and methods Numerous recent patents on freezing devices suggest the term "pioneering" to describe the present status of food freezing equipment In the field of refrigeration equipment the new Freons (302) are finding wider application as refrigerants and the direct expansion is preferred in some cases over the brine system Refrigeration equipment manufacturers predict an expanding market for freezing and air conditioning machinery, for cold storage cases and space in retail and wholesale food establishments for refrigerated trucks and rail cars, and for all sorts of refrigerated equipment on ships

The tedious hand labor steps in the preparation of foods continue to yield to new automatic machines, such as the fish filleting machine (303) Methods of peeling root crops have been studied extensively (304, 305, 306), but this problem deserves and will undoubtedly receive more attention Ways to save steam heat, to cool water, and in general to operate the processing equipment more efficiently are frequently reviewed (307, 308, 309, 310, 311). Pasteurizing and deaeration are reported to be effectively accomplished for dairy products in a new mechanism (312) Deaeration and pasteurizing equipment has been required for the developing juice industries. The newer equipment materials are stainless steels (313), glass (314, 315), and plastics (316)

No one subject has created more interest than the application of high frequency heating to food processes. Research has endeavored to substitute electronic heat for every purpose for which heat is required, i e, for inactivation of enzymes, sterilization, and defrosting, and technical reports covering the subject are numerous (317). The progress of these studies has thus far resulted in primarily greater understanding of principles and problems rather than in actual applications (318, 319, 320, 321, 322, 323, 324, 325) Improved ability to generate heat uniformly in food substances, which are structurally non-uniform, would rank as a great achievement. The use of the electronic principle in grading eggs has been attempted (326).

Devices and methods for objective measurement of grades and qualities are likewise important in food technology. They are important both in grading raw materials and in estimating quality of the final product For the quality control staff in a plant they are important in following product changes during processing and storage Some metric devices are chemical, whereas others are mechanical (327, 328, 329, 330, 331) These tests and devices will undoubtedly continue to be developed and used along with taste testing (also referred to as organoleptic testing and as psychometric testing) War experience has led Quartermaster officials of the United States Armed Forces to initiate elaborate studies of his sort, particularly at the Food and Container Institute in Chicago, not only for the purpose of food evaluation but also to create a substantial body of knowledge of food preferences and consuming habits

Equipment related to increase in comfort and efficiency of workers includes illumination (332, 333, 334), mechanized handling (335, 336, 337, 338, 339), and control devices and instruments (340, 341) These represent modern efforts to improve the economy of plant operation and also to meet the demands of labor for better jobs and working conditions

Illustrations were provided by American Iron and Steel Institute, International Nickel Co, York Corp, Fish Machinery Corp, Dow Corning Corp, Goodyear Tire & Rubber Co, Romanoff Caviar Co

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CHAPTER XI

GLASS, PORCELAIN AND CERAMIC INDUSTRIES

by G. H. McINTYRE

Porcelain enamel is an inorganic, glass-like material, fused to an iron or steel base at a temperature of usually between 1,500 and 1,600 deg The resulting coat has a smooth, glossy surface and is held firmly to the metal by both mechanical and chemical means

Years ago the value of porcelain enamel lay in the beauty created by it, today, porcelain enamel is usually thought of in terms of the services that it renders Modern research, spurred on in the past few years by wartime necessity, has brought out a wider variety of useful properties of porcelain enamel than were recognized before New porcelain enamels, incorporating these superior qualities, are now available to manufacturers, and it is anticipated that these enamels will continue to broaden their application for domestic, commercial, and industrial use

So many and so varied are today's porcelain enamels that it is necessary to regard the phrase as the family name of a large group, rather than as denoting a single substance In selecting a porcelain enamel, the manufacturer specifies the condition under which his product is to operate, and a porcelain enamel is selected for this service Thus, enamels may be chosen for resistance to abrasion or gouging, to acids or alkalies, to atmospheric corrosion, or to heat

Since porcelain enamels are vitreous coatings fused to metal, the problems which have been encountered require consideration not only of the coating itself but also of the base metal, its fabrication and cleaning plant operation and equipment, and the materials required in the enamel frit formulation as well as those used as mill additions Research in the porcelain enamel industry, therefore, is to a considerable extent a cooperative endeavor carried on in the laboratories of the steel companies, frit manufacturing companies, chemical supply houses, the universities, and in the form of fellowships provided by such industry-wide associations as the Porcelain Enamel Institute and the Enameled Utensil Manufacturers Council.

The production of porcelain enamel and porcelain enameled articles was greatly curtailed during the war years. All frit manufacturers and most plants in the field devoted nearly all of their efforts and manufacturing facilities to war goods which seldom had any connection with porcelain enameling. In spite of this, progress did not cease and the frit companies, especially, were able to devote a considerable amount of their research energy and talents to the development of new finishes and techniques.

SHEET STEEL ENAMELS

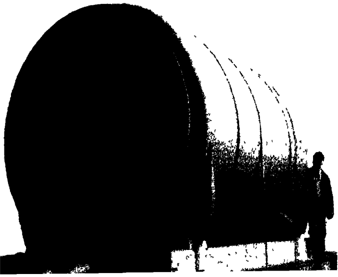
Pressed steel sanitary ware was being produced prior to the cutbacks for war production and it appears that the future manufacture of such articles will be extensive This type of porcelain enameled article needs special ground coats and cover coats because of the long firing cycle required Developments have continued during the past several years and it can be now stated that both ground coats and cover coats are available which are especially adaptable to this type of ware

Ground Coats

One of the most important contributions to the industry is the ground coat which will mature at the same time-temperature cycle as that required for the average sheet steel cover coat Such a ground coat is particularly desirable for jobbing shops and those porcelain enameling shops that utilize continuous furnaces It eliminates the necessity of banking the parts to be fired in the ground coat, as these can be hung on the furnace chain or fired in a box furnace simultaneously with other parts being fired in cover coat In addition to the advantages of production gained by firing ground coat and cover coat at the same time, economies are realized because of the low firing temperature required for this type of ground coat. There is also less warpage tendency, which often permits the product to be made from lighter gauge metal

High Speed Blue Ground Coat Prior to the postwar period, the enameling industry had for the most part

Lined with porcelain enamel, tanks like this are extensively used for storage or processing of beverages and foodstuffs.



always considered as fundamental the axiom that the blue ground coat must be so compounded that substantially higher firing temperatures would be required for its proper maturing as compared to those of the cover coat to be employed with it. This was true because of problems of sagging, pulling through of the ground into the white coat and generally unsatisfactory results if the maturing temperatures of the two types of enamels were made too similar.

The first major change in this situation came about in 1945, when blue ground coats were introduced which would mature at exactly the same time and temperature as the companion cover coat, with actually superior results as to resistance to normally expected ground coat defects This was not accomplished by raising the maturing temperature of the cover coat, but by so compounding the ground coat enamels that complete bonding to the metal base was secured at cover coat temperatures without any of the heretofore expected defects

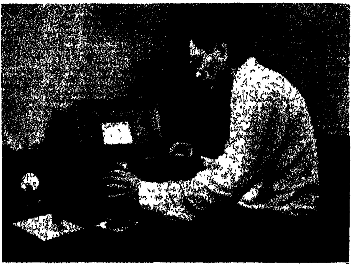
This lowering of firing temperature immediately demonstrated many advantages to the stove designer and the enameler The designer could use lighter gauges because of less warpage, and the enameler could simplify his production by firing both cover coat and ground coat on the same furnace chain at the same time These advantages also applied to the box furnace operator, since banking of the ware was no longer required This type of ground coat has now been universally accepted, not only in the United States and Canada, but in Europe and England as well.

The ground coat has been widely accepted during the past year and is used for many types of products, including flatware, washing machine tubs and specialty items.

Cover Coats

Formerly, porcelain enamel opacification was largely dependent upon fluorides fortified by considerable amounts of tin oxide added during the milling operation Upon investigation, four other materials showed promise as mill-added opacifiers—antimony oxide, zirconium compounds, titanium dioxide and arsenic oxide. The fourth named has been widely used as an opacifier in jewelry enamels, suitable for use on sheet iron. Tin oxide, although suitable, is too soluble in enamel glasses to be added to the raw batch. During the decade 1920-1930 the antimony-opacified enamels were continually improved and the opacification greatly increased. From 1939 to 1946 the introduction and the development of highly opaque zirconium-opacified enamels made possible further improvements in covering power and decrease in application weight

Photovolt Reflectometer for the measurement of light reflected from an enameled surface.



Zirconium Enamels The most important sheet steel enamel development during the past several years has been zirconium-opacified sheet steel cover coat porcelain enamels. These have almost entirely replaced the former non-acid resisting antimony bearing enamels The advantages of zirconium over previously accepted super-opaque antimony cover coat enamels are wider firing range, greater coverage, improved surface texture and gloss, less sagging tendency and generally thinner coatings for the same degree of whiteness.

Acid-Resistant Cover Coat Enamels The standard acid resisting enamels that were manufactured prior to the war are still in use An entirely new development is about ready for commercial exploitation which is neither zirconium nor antimony bearing It is based on the use of titanium, both as a mill addition and in the formulation of the frit

Titanium Enamels The comparatively new titanium opacified porcelain enamels have created a great deal of interest in this field. The fact that these enamels will produce sufficient opacity (white covering power) at 15 to 18 grams per sq ft accounts for this general interest These enamels are mostly of the acid-resisting type, which widens the field of possible uses Satisfactory draining qualities of the titanium enamels at 18 to 25 grams per sq ft. is another attractive attribute.

With these new porcelain enamels coming into production, it should be of interest to trace the progress of their development As early as 1936, research investigations indicated that opacification with titanium in the frit was a possibility. The type of frit wherein this possibility was noted was not commercial in any way. Previous to these studies there had been considerable interest in the use of titanium as a mill addition opacifier This interest was based on the known opacifying power of finely divided titanium dioxide and the assumption that this state of titanium dioxide could be maintained in the fired enamel when the titanium dioxide was added to the mill.

Investigations were continued until the outbreak of the war in 1941 and they established some of the requirements for opacification with titanium. It may be assumed that practically all laboratories interested in the development of porcelain enamel frits had begun following some program of research on the titanium opacified type of frit by the outset of 1945. Production trials were made by at least one manufacturer as early as March, 1945, and an enamel of the titanium opacified type was in actual commercial production by July of the same year. The excellent results obtained stimulated the interest of the industry and produced a demand for this type of enamel to meet various prevalent operating conditions Competitive frits soon appeared on the market and served to add still further emphasis to the demand

The record of improvement in this type of enamel includes a more satisfactory white color, more acid resistance, and an operating range which allows a greater field of utilization for this enamel Among the ware being enameled with these titanium opacified frits are hydrator pans, sanitary ware, hollow ware, electric light reflectors, table and stove tops Experimental runs have been made on practically every item which is at present porcelain enameled with a white finish Most of these trials show much promise for the future of titanium opacified enamels The production of titanium opacified enamels during the years 1945-46 made possible a reduction in application weight of 50 per cent over the best previous material, as well as increased surface hardness and a high degree of acid resistance.

Economic factors such as the availability of raw materials or shortages of other materials which are at present used for other types of white enamels will have their influence on this trend to the new type frit At the present time there is a distinct possibility that the titanium opacified enamels can be adapted for use in the new one-coat-direct-on-steel The opacification obtained with titanium dioxide would make this a desirable type of enamel for such work

One-Coat Finishes

One-Coat White. Considerable publicity has been given to the application of one-coat white finish directly to special types of steel It is important that the cleaning and pickling operations be conducted under extremely well-controlled conditions, in order that full advantage might be gained from both the special steel and the enamels.

Molybdenum Enamels The ever-present demand for a white porcelain enamel that can be applied directly to steel to yield a finish coat capable of meeting high inspection standards has fostered the development of molybdenum-bearing enamels over the past few years The unique properties of molybdenum compounds which permit their use as adherence-promoting agents and as opacifying materials have focused attention on their use in the development of one-fire white finishes. As early as 1935 it was reported that the smelting of antimony oxide and molybdenum oxide in a frit gave some evidence of adherence Shortly afterwards it was found that a deposit of a hydrated sub-oxide of molybdenum formed by electrodeposition on the surface of sheet steel caused a white enamel to adhere tenaciously. Kautz studied a number of antimony and molybdenum compounds and their application in both clear and white enamel compositions In a series of papers published in the *Journal of the American Ceramic Society,* he describes white enamel compositions which have antimony and molybdenum smelted in the frit. These frits adhere to sheet steel without mill addition adherence-promotion agents. Among the enamels described are white ground coats, non acid-resisting cover coats and acid-resisting cover coats These enamels were designed to be fired in the same temperature range as commercial cover coat enamels

Another development of interest is based on the use of molybdenum and antimony compounds as mill addition adherence-promotion agents in commercial cover coat enamels For example, commercial zircon cover coat enamel under proper conditions of firing will adhere to some enameling steels when milled with barium molybdate and antimony trioxide Generally, nickel flashing is essential to obtain adherence with this type of enamel, although all steels will not produce adherence under these conditions In general, the adherence of cover coats processed in this manner does not compare with the adherence obtained with enamels which have molybdenum and antimony as an integral part of the frit

Molybdenum has played an important part in the development of one-coat white finishes which can be fired at lower temperatures than conventional cover coat finishes These enamels contain molybdenum as an integral part of the frit and may or may not contain antimony They are designed to fire at temperatures ranging from 1,250 deg to 1,400 deg F., and adhere to a wide variety of nickel-dipped steels At application weights of 45-50 grams per sq ft reflectance valued in the neighborhood of 70 per cent are obtained

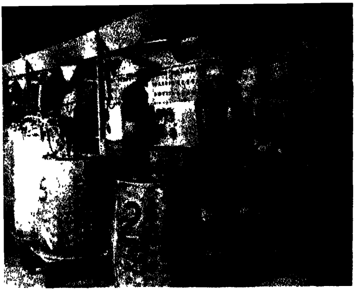
Molybdenum enamels are being used commercially in a limited and experimental manner at present Their chief advantage is that they provide a one-coat white finish which will adhere to steel The higher cost of materials required to produce molybdenum enamels necessarily increases their relative cost, but considerable compensation for this may be had in a reduction in the number of firing operations and in a potential lowering of firing temperatures A single firing operation will provide additional compensation in increased production

Regardless of the commercial aspects of molybdenum porcelain enamels, it should be recognized that experience with them has afforded information and stimuli valuable to the advancement of the technology of one-coat white finishes applied directly to steel

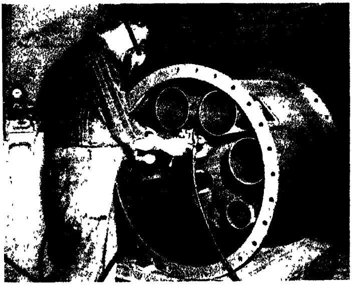
One-Coat Colors

It is now also possible to produce dark colors (blues, greens, grays, and browns) in one coat directly on sheet

Research Building of American Rolling Mill Co. has exterior facing of attractive porcelain enamel.



Stove tops receive coating of acid-resisting enamel, an important special porcelain enameling surface.



Spraying a submarine silencer with a wet-process porcelain enamel is conveniently accomplished with compressed air.

Porcelain finished exhaust mufflers have proved highly satisfactory in automotive, marine and aviation fields.

steel. These colors can be grained or stipled, if desired. They develop excellent gloss and good surface characteristics, as well as good bond. They are suitable for many architectural and corrosion resistant purposes, for oven liners and other applications where dark colors are suitable.

Low-Temperature Enamels

There is keen interest in the work being done to formulate porcelain enamels that will mature or fuse at temperatures lower than the 1,500-1,600 deg F required for conventional types. Such low-fired enamels, if feasible, would help products which have been highly stressed by forming operations to hold their shape when subjected to enamel-fusion temperatures. It has already been pointed out that molybdenum enamels now figure prominently in the low-firing group.

Coating Thickness

Another goal toward which the porcelain enamelers are working is thinner coatings. Reducing the thickness of the coatings is desirable primarily because it lowers cost of application and increases serviceability. The thinner coating makes possible greater flexibility and impact resistance, thus permitting a wider range of product design. Today's improved porcelain enamels and improved enameling irons have permitted the establishment of specifications for ordinary work of 0.015 in. or less.

STAINLESS STEEL ENAMELS

The term "stainless steel" is used rather loosely to include any or all of the metals and alloys which resist corrosion and chemical attack. This term is probably more often used to designate the types of stainless steel containing approximately 18 per cent chromium and 8 per cent nickel, commonly called "18-8 stainless." There are several types of 18-8 stainless having basically the same chemical composition, but varying in the percentage of impurities and in the materials added as stabilizers.

Commercial enamels can be applied to some of the stainless steels. These steels being non-gasing, the results are most satisfactory. The hazard of fish scaling is completely eliminated, surface imperfections are minimized, and the firing range is wide as compared to the same enamel applied to normal enameling iron. The following observations are pertinent to stainless steels suitable for enameling.

Adherence developed by zirconium cover coat enamels applied to sandblasted stainless steel is comparable to that developed by normal cobalt ground coats on enameling iron. Ground coat enamels adhere just as tenaciously as do the cover coat enamels.

Sandblasting stainless steel gives a surface that is readily enameled. Sandblasting is an expensive operation and most manufacturers would prefer to clean and pickle in tank baths. Pickling stainless steel for porcelain enameling has offered a considerable problem. The 18-8 stainless steels listed above can be pickled in strong oxidizing acids. The strength of the acid must be increased for the more resistant types. The pickling time is critical and must be sufficient to give considerable etch. A white cover coat enamel applied over a pickled surface is inclined to develop spotty adherence, and adherence may be lacking altogether There is some evidence to support the hypothesis that the mill procedures, necessary in producing stainless steel sheets, develop a skin effect which is detrimental to enameling Sheets with a bright or polished surface will be more difficult to prepare than sheets which have been mill pickled

There are certain inherent advantages gained where stainless steel is used for porcelain enameling to replace regular enameling iron The advantages are

1 A lighter gauge metal may be used due to the greater strength of stainless steel at room and elevated temperatures, and the resistance to sagging
2 The ground coat can be eliminated, saving the cost of material, application, and firing
3 Stainless steel is non-gasing and rejects will be minimized by eliminating fishscaling, and any blistering or copperheading due to occluded gases
4 The elimination of the ground coat reduces the overall enamel thickness thereby reducing the hazard of failure from mechanical shock
5 Sharp edges, which cannot be coated with any degree of assurance, are not subject to corrosion at normal temperatures in normal atmospheres
6 Enameled stainless steel parts may be subjected to more repeated firings at higher temperatures without over-firing
7 Ceramic coated stainless steel parts are less subject to corrosion and subsequent deterioration when such parts are subjected to excessive temperatures
8 Unique decorative effects can be obtained by coating part of the metal surface and polishing the uncoated areas after enameling

The advantages listed will not overcome the difference in cost between 18-8 stainless steel and normal enameling iron and the added cost of sandblasting, but the benefits are real. There are, no doubt, applications in the specialty field where parts of porcelain enameled 18-8 stainless steel will give the desired quality and service life. The volume of stainless steel being porcelain enameled today is almost negligible, but indications are that it is due to receive favorable attention in the near future.

ALUMINUM ENAMELS

Porcelain enamels can be used for both protective and decorative coatings on aluminum Some interest has been expressed in the possibility of using aluminum in combination with porcelain enamel for signs, lightweight molds, architectural parts, and even for household appliances Porcelain enamels have been developed which have good adherence on both cast and sheet aluminum. The surface can be cleaned with organic solvents or lightly sand-blasted. The firing temperature is in the neighborhood of 950-980 deg. F and the time generally from 15-30 minutes. A long low-temperature firing cycle is required, because of the low fusing point of aluminum.

CAST IRON ENAMELS

Very few, if any, new developments have been reported on dry process and wet process cast iron enamels There has been practically no cast iron enameling carried on in the U S during the past decade

CORROSION-RESISTANCE

Porcelain enamel is a highly corrosion-resistant inorganic substance Generally, it has been used commercially not so much because of this property, but for the reason that it is colorful, durable, easily cleaned and economical to apply Its possibilities as a functional finish—strictly for high corrosion resistance—have only recently been recognized and exploited

Porcelain enamels can be made highly resistant to all organic and inorganic acids (except hydrofluoric) and to normal alkaline solutions They are not resistant to highly concentrated caustic solutions at boiling temperatures, since these solutions are excellent solvents for silicates All porcelain enamels are not made acid resistant because, in general, these types of enamels are more difficult to apply, which means relatively higher costs in the process Acid resistance does not always guarantee that the finish will be suited to the conditions of service For example, weather and water resisting enamels may be also acid resisting, but all acid resisting enamels are not weather and water resistant

During the war, many new types of corrosion resistant ceramic coatings or porcelain enamels were developed for ferrous metals It was found that many articles formerly manufactured from heat resistant and corrosion resistant metal alloys could be manufactured at lower costs from available low-carbon enameling stock and mild steel (SAE 1020) and coated with one or two coatings of special porcelain enamels These items were frequently found to be better than the originals made from metal alloys This was particularly true for engine exhaust systems of airplanes and tanks

Ground coat of heat-resisting enamel is applied by dipping exhaust stack. This covers inside and outside surfaces.

New types of porcelain enamels were produced and used in the manufacture of hot water storage tanks for government and private housing Porcelain enamels completely resistant to the solvent action of hot water to pressure had not been discovered prior to the war Such finishes are now available and undoubtedly will be extensively used. Other examples of applications of porcelain enamels for corrosion resistance are "glass-lined" pipe used successfully to resist hydrogen sulfide corrosion in natural gas fields.

Another interesting new type of porcelain enamel coating application during the war was the manufacture of domestic electric stove heating elements from porcelain tubing The tubing was used as the medium for the hot electric wire These coatings were of a highly infusible type and were durable at high temperatures This application permitted the manufacture of replacement range parts during the war, even though nickel tubing was no longer available.

NEW APPLICATIONS

Hot Water Tanks

During the war period it became increasingly difficult to secure galvanized and metal alloy hot water tanks. A large quantity of porcelain enameled hot water tanks were manufactured by several companies At first, considerable difficulty was encountered in eliminating porcelain enamel defects, which were sources of corrosion when the tanks were placed in service It is important to know that hot water under pressure is an extremely corrosive material, especially when it contains small quantities of dissolved oxygen and carbon dioxide. Special porcelain enamels, both for gound and cover coat, are required to withstand these conditions While it is true that a porcelain enamel suitable for this purpose is considerably acid resistant, it is distinctly not true that all acid-resistant enamels can be considered water resistant.

It is anticipated that considerable porcelain enamel will be consumed for the manufacture of hot water tanks in the postwar period, as numerous companies have indicated their intention of producing this item.

Transformer Cases

Another new item which lends itself to porcelain enameling is the electrical transformer case, particularly the type that is normally installed on poles and exposed to the weather. The usual painted case must be repainted frequently, in order to prevent corrosion. It is reported that the cost of refinishing these cases one time closely approximates the cost of porcelain enameling in one coat Attractive colors may be obtained with the new one-coat finish porcelain enamels and the corrosion problem is reduced to a minimum.

Heat-Resistant Coatings

During the war many items formerly made from heat resistant metal alloys were fabricated in regular enameling stock or 10-20 steel and coated with special porcelain enamels. Airplane exhaust stacks, amphibious landing-barge exhaust equipment, electric stove heating elements, and electric stove reflector pans have been finished in these special heat-resisting coatings The usual type of finish on exhaust systems and for electric stove elements has a matte surface, while the reflector pans have been coated in acid-resistant ground coat

The refractory qualities that can be built into porcelain enamel can be appreciated when it is realized that some new coats with thicknessses of 0 004 in are able to withstand exposure to temperatures above 1,500 deg F Such enamels are able to function satisfactorily even when subjected to sudden and pronounced drops of temperature These special refractory-type coats are being explored further to find out whether they can be used on jet turbines where the rapid destruction of the housing metal at the high temperatures of operation is a serious problem

Air Markers

Porcelain enamel is rapidly finding a new and important use as a coating for steel air markers The need for a more widespread use of such aviation aids has been felt for some time, and many of the states are preparing regulations for their effective use The greatest need for air markers is probably felt by flyers of personal planes, since commercial ships must fly on radio beams The small plane owner needs air signs just as the automobile owner needs road signs, to indicate the right direction

The principal advantage of porcelain enameled markers is their very low maintenance requirement, which might consist of a washing every three or four years On the other hand, there is no weathering and their durability can be expected to hold for twenty years Moreover, porcelain enameled markers are relatively inexpensive, as compared with painted signs Although having an initial cost of approximately $250, enameled markers will last about ten times as long as the painted variety

Early this year an eastern enameling concern donated a porcelain enameled air marker to the local Junior Chamber of Commerce for erection on the company's plant roof The letters and numbers of the chrome yellow marker are constructed of 16 to 20 gauge steel in panels up to five feet long and a little over a foot in width. (The 16 gauge steel is used where the surface must support a man's weight, as in the case of a large ground marker.) This particular marker is visible at about 300 feet.

For signs of a permanent nature, porcelain enamel has always enjoyed great acceptance The factors of enduring finish and non-fading colors are the major reasons for this. Especially are porcelain enamel signs a necessity in coastal areas, where they must withstand corrosive salt air and weather conditions.

Flue Linings

Wartime research and development have demonstrated porcelain enamel's value for such uses as chimneys and flues. Many building codes already require this type of flue lining with certain types of fuel. Porcelain enameled chimneys have been shown to have a number of important advantages: no foundation is required; greater draft per foot of chimney height; lower exterior surface temperatures, quick and easy installation, and high efficiencies for automatic heating equipment

Architectural Enamels

Enameled Steel Panels· By virtue of its proved performance in the stove, refrigerator and plumbingware fields, porcelain enamel was adopted some years ago as a permanent dress-up finish for such retail establishments as gasoline filling stations, theaters, stores and restaurants Owners of such establishments readily visualized the considerable sales appeal of a building modernized with porcelain enameled steel panels They understood, too, how such panels would give store fronts a long life and at the same time reduce maintenance cost to its barest minimum.

Porcelain enameled steel is also beginning to take its place as an important building material in its own right, since it not only assures a structure that is fireproof, ratproof and termiteproof, but also embodies convenience, utility and beauty The extensive use of porcelain enameled steel by major oil companies for the construction of service stations has been an important factor in its expanding value as a general building material These companies, with construction programs involving hundreds of identical buildings, are most cautious in selecting building materials which are attractive and durable, economical to construct and maintain

Architectural porcelain enamel is also rapidly becoming an important feature in postwar housing, as one of the materials in the all-steel prefabricated home The idea of mass-production all-steel home building has appealed to architects and builders for some time, but only recently have their plans begun to pass from the blue-print stage to active production schedules Two business enterprises—Higgins, Inc and the Lustron Corporation—have been most energetic in the development of these highly attractive and utilitarian housing units The former concern, well-known for its wartime record of shipbuilding, has developed a new building material consisting of porcelain enamel-on-steel panels available in a variety of colors and textures Panels are prefabricated with the electrical and plumbing outlets installed at the factory Equally as flexible as other building materials, prefabricated panels may be erected in accordance with any architectural design

Architectural Specifications: Standard specifications covering the manufacture of architectural porcelain enamel have been officially approved and adopted by the Architectural Division of the Porcelain Enamel Institute The standards prescribe in general detail the proper materials and methods to be used in designing, fabricating and processing parts for architectural porcelain enameling. They were prepared by a special committee with the aid of a highly skilled architectural specifications writer, and are concisely phrased in terminology familiar to the architect.

Architects have been handicapped in their desire to utilize porcelain enamel more widely, because there has been a lack of authoritative information on specifications which will insure a high quality of manufactured product. The new standards have been developed to meet this need, and the Architectural Specifications Committee is presently engaged in promoting public confidence in the serviceability of porcelain enamel structures

IMPROVED ENAMELING PROCESSES

Nickel Dipping

It is essential for enameling that all grease, soil, rust and welding scale be removed from the steel surface. This is usually effected by an alkaline cleaning solution and hot sulphuric acid There are many good commercial alkaline cleaners giving best results when maintained at boiling temperature and at concentrations of approximately 6 to 8 oz per gal of solution After having been cleaned and thoroughly rinsed, the parts to be enameled are immersed in sulphuric acid at a temperature of 160 deg F Time of immersion is usually 10 to 15 minutes or until all scale and rust are removed There should be some etching of the surface Inhibitors are generally not used in connection with pickling of steel for enameling The ware may or may not be rinsed after the acid etch

The next step is the nickel dip operation Importance of a good nickel flash in lowering rejects and insuring generally good enameling qualities of all types of steel cannot be overstressed (This does not apply to the newer steels with surfaces plated at the mill) A good nickel deposit of from 0 04 to 0 08 grams of nickel per sq ft of metal surface improves the bonding range of the ground coat to the steel, and minimizes copper heading and fishscaling by reducing overactive oxidation characteristics of the steel The enamel is bonded to the steel through absorption of a uniformly adhering oxide layer into the enamel layer The nickel flash regulates the quality of this oxide layer.

For good porcelain enameling practice, it should be the aim of every shop operator constantly to control all operations throughout the shop For successful nickel application, control is a must It may be truly said that all difficulties encountered in utilizing a nickel flash, and any doubt as to the advantages gained, are due to a lack of appreciation of the importance of uniform conditions of the solution and treatment

Most authors, researchers and shop operators agree that temperature of the bath, concentration of nickel salts, and degree of acidity of pH of the solution are of prime importance and must be controlled within narrow limits In addition, such factors as time of immersion, sequence, and methods of rinsing before and after the nickel flash, interval of exposure to air between each step in the process, thickness of nickel coating, type of steel surface being treated and proper removal of sludge, have important bearings on the quality of the resultant coating. When a set of conditions for the nickel flash sequences are once determined for satisfactory performance in any given shop under normal operation, those conditions should always be maintained to a point within a practical narrow limit of variation.

Large scale production procedures as well as research have shown the following conditions and sequence of operation to give effectively nickeled steel without the dangers of iron salts:

1 After the acid pickle–5 minute rinse in sulphuric acid at room temperature
2 Nickel dip–Solution should contain ¾ to 1½ oz, preferably 1 oz single nickel salts per gal Maintain acidity by pH 3 5 with addition of sulphuric acid or sodium hydroxide Do not use boric acid as a buffer as this promotes excessive formation of complex iron salts Ammonia and ammonium carbonate additions should be avoided for the same reasons Temperature of the bath should be 155 to 160 deg F Under these conditions the ware should be left in the bath a sufficient length of time to deposit 0 04 to 0 08 grams of metallic nickel per sq ft of metal surface The lower range is satisfactory for the average blue ground coat, while the heavier deposits usually are best for white enamel directly on the steel
3 Do not use a rinse If it is felt absolutely necessary, a short rinse in sulphuric acid of pH 3 0 is effective The time interval between the nickel flash and the rinse, as well as between the rinse and the neutralizer, should be extremely short
4 Two neutralizer tanks should be available, the first made up in fairly strong solutions and the second weaker Suggested conditions are (a) 0 04 oz per gal sodium cyanide, 0 02 oz per gal sodium hydroxide, temperature 140 deg F, time 1½ minutes immersion (b) 0 12 oz per gal sodium cyanide, 0 10 oz per gal sodium hydroxide, temperature 140 deg F, time 2½ minutes immersion Carbonates should be avoided in the neutralizer, since these have been found to hinder cyanide removal of ferrous salts

Spraying

Formerly, all applications of the porcelain enamel to the metal was done by dipping Today the spraying method is also in general practice Spray coating is better confined to relatively plain shapes such as stove panels, because there is danger of incomplete coverage of the more complicated parts At least one large producer of ranges has automatically sprayed both ground coat and cover coat on flat panels for several years Other porcelain enameling plants are putting in installations of this kind The ground coat can be applied more uniformly and much more thinly, with a higher quality finish and less likelihood of damage to finished parts

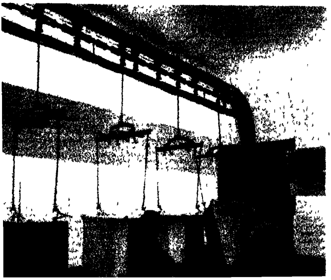
Many porcelain enameling shops also apply cover coat enamel on essentially flat parts by means of automatic spraying machines By controlling the consistency of the porcelain enamel carefully, the same advantages are gained for the cover coat as described for the ground coat

Another method of automatic spraying that has received some attention is the Ransburg Process of electrostatic spraying, in which the work passes through a highly charged electrostatic field Electrostatic spraying of porcelain enamel has been introduced for use where very thin coatings are desired, and where it can be applied, results claimed for it are a considerable saving of time, labor and materials The electrostatic process involves the charging of spray particles in an electric field and the attraction of these particles to the ware which is to be enameled The work is made negative and the spray is positively charged The process, originally designed for spraying organic coatings, shows promise for use with porcelain enamel slips By eliminating overspray and producing a coating of uniform thickness without waste the electrostatic method tends to reduce losses in material increase quality, and lower cost of production It is evident that for flatware the spray can be so adjusted that the loss in porcelain enamel is reduced from the usual 40-50 per cent to approximately 20 per cent

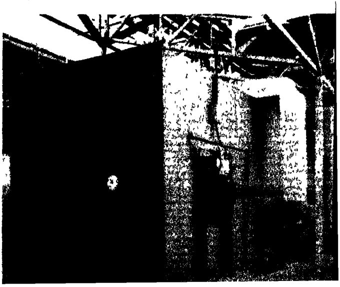
TESTING OF PORCELAIN ENAMEL

Tests developed through research at the National Bureau of Standards and sponsored by the Porcelain

Example of a modern porcelain enameling inspection room. Pieces move through inspection on overhead conveyor in well lighted room.



Built to bake big buses, this 40 ft. chamber oven was recently installed in Monterrey, Mexico, to finish bake transport buses. Gas-fired oven has automatic controls.



Enamel Institute have enabled enamelers to determine the relative merits of various formulas. New equipment for testing the qualities of porcelain enamel include the Photovolt Reflectometer, the Gouge and Scratch test machine and abrasion tester, and the thermal-shock and acid-solubility test equipment of the Enamel Utensil Manufacturers Council.

Porcelain enamel has a high reflectance not only when new but after a considerable passage of time. A reflectometer is used to measure the amount of light reflected from any enameled surface. The Photovolt Reflectometer employs a scanning head with light source, filter and photo-sensitive cell. It indicates reflectance directly on the scale of a millivoltometer calibrated in per cent reflectance. The instrument is set to read correctly on a panel of known reflectance. It is portable and valuable for production control, since any surface can be read without injury to the product.

The resistance of porcelain enamel to deep scratching or gouging is measured by the penetration of a steel ball into the enamel under a given load. Surface scratching or abrasion resistance from constant handling or cleaning powders is measured in terms of the time required to remove the gloss under the abrasive action of a standard quality of feldspar. In constant testing, the time required to show the slightest effect on any grade of porcelain enamel is far in excess of that required to destroy the most abrasion-resistant synthetic coatings.

Much guesswork has been eliminated from the potential wearability or resistance to rubbing abrasion of ceramic finishes and surfaces by the development of a precision-designed, electrically-operated instrument known as the *Taber Abraser*. This instrument, which may be applied to glazed and glass, as well as to enameled surfaces, has the function of duplicating, in measurable terms, the rubbing abrasion that a surface coating encounters under actual service conditions. Directly actuated by a rotating specimen holder, the counter on the unit automatically records each wear-cycle as it occurs. The total number of wear-revolutions thus secured and registered affords a calibrated precise report of the material's wear characteristic, and may be employed for either immediate or future comparison. Such data can prove exceedingly valuable in connection with basic research and product analysis.

The gouge and surface abrasion equipment utilized in connection with porcelain enamel are valuable principally as research instruments being, as yet, not practical for production control. The thermal-shock and impact-test machines, however, are research instruments which may readily be adapted to production use.

SPECIFICATIONS

The porcelain enameling industry has become more specification-minded, possibly as a result of the war. All porcelain enamel frit producers and consumers had to deal intimately with government and Army-Navy specifications for the production of war material, and they have thus come to realize the advantages of clear-cut specifications for the production of goods of uniformly high quality.

The industry's technicians are writing specifications for higher quality and uniform porcelain enameled products. The Enameled Utensil Manuafacturers Council has established a co-operative laboratory at the University of Illinois for the preparation of specifications covering construction, porcelain enameling, thermal shock and impact resistance. Member companies of the Council may have their ware tested and may receive a report comparing ware produced by them with that produced by the industry as a whole. Certainly this is a desirable step toward a higher quality finish.

A division has been formed within the Porcelain Enamel Institute to study and improve specifications for architectural porcelain enamels as has been stated earlier. The sign manufacturers are attempting to draw up specifications for their industry, and the table-top manufacturers already have specifications for porcelain enameled table-tops. Finally a committee has been created by the Institute to prepare workable tests and specifications for the porcelain enameling industry as a whole. There is every indication that this movement toward standardization and improvement will be continued and expanded.

HIGH-TEMPERATURE CERAMICS

"Super Metals" for Gas Turbines

New and revolutionary forms of power generation and transportation are being developed by the Army and Navy which will require stronger and more heat-resistant materials. The gas turbine, which has been made possible only by use of highly alloyed materials produced in the last five or ten years, requires materials able to withstand high stresses and temperatures up to 1,500 deg F. Now engineers are calling for materials designed to withstand 1,600 deg F and stresses as high as 20,000 lb per sq in.

Supercharger disc materials, for example, must withstand a temperature of 110 deg F under high stress; for this purpose, chromium-nickel-cobalt-iron alloy strengthened with such other elements as molybdenum, tungsten, columbium or titanium is used. Showing promise for use under higher stresses and temperatures is another series of alloys based on percentages higher than 50 per cent of chromium.

These high-temperature metals developed for the gas turbines and improvements on these yet to come will be useful, but to meet the highest temperatures these will not suffice and ceramic materials will be called for. These ceramic materials, made up from the most highly refractory substances such as oxides of beryllium, magnesium and zirconium, are the only known materials that will not melt or burn up at such temperatures. They may be used as coatings for metals, as structural combinations with metals, or as individual parts. The relatively poor mechanical properties of ceramic materials, as compared with those of metals, may soon be improved or compensated for by design.

High Dielectric Ceramics

New ceramic dielectrics having exceptionally high dielectric constants have been evolved at the National

Bureau of Standards, as a result of extensive research Such dielectrics are of major importance in the production of capacitors for use in radio, radar, television, and in other special equipment where space is at a premium. Their extremely high dielectric constants also make them particularly adaptable for the tiny capacitors required in subminiature electronic devices.

The unusual electric properties of the naturally occurring titanium dioxide mineral, rutile, have been known for more than forty years and have been useful in radio design for about twenty years However, the high values of dielectric constants for some of the titanates were not observed until shortly before World War II Because of the urgent need for such dielectrics, the Signal Corps in 1944 requested the National Bureau of Standards to develop and test ceramic dielectrics The subsequent investigation has covered a study of the properties of dielectrics prepared by systematic variation in the composition of the alkaline-earth titanates

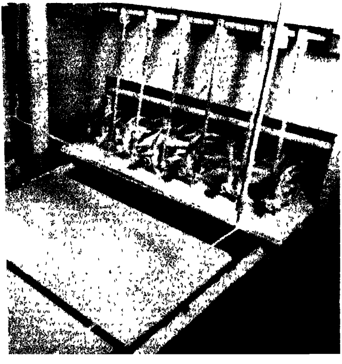
High-Temperature Coatings for Exhaust Systems

Early in the war, supplies of many materials were inadequate to meet essential war demands Nickel and chromium were particularly scarce because of the greatly increased demand and also because the normal importation of these metals was endangered.

To alleviate this situation, a project was undertaken at the National Bureau of Standards which included (a) development of special heat-resistant ceramic coatings for low-carbon steels, and (b) testing of the new coatings in direct comparison with the conventional type of glossy porcelain enamels

In order to avoid the necessity for extremely high smelting temperatures, conventional ground-coat frits were used, and refractoriness of the coatings was increased by mill additions Zirconium oxide, titanium dioxide, ferric oxide, aluminum oxide, chromic oxide, silicon dioxide, silicon carbide, feldspar, mullite, and chrome ore were added in various amounts

Electro-static spraying is accomplished by spraying enamel into field created by cross wires. The enamel particles are attracted to the wire in an even, uniform coating with a minimum loss from over-spray or dust.



These coatings were milled, applied and fired by the methods for porcelain enamels The specimens were then examined for surface texture and adherence Those that showed promise were heated for short periods at 1,650 deg F, in order to obtain an indication of their resistance to deterioration at high temperature Of the various coatings tested, those containing alumina gave the best results

The thermal expansion is higher for the new coatings than for many ground-coat enamels Experience has shown, however, that these new coatings should not be applied in as great a thickness as conventional ground-coat enamels, because thick applications tend to chip spontaneously

Numerous laboratory tests were made on the coatings developed at the National Bureau of Standards as well as on conventional type coatings submitted for trial by a number of manufacturers The laboratory test conditions were chosen to simulate operating conditions in airplane exhaust systems, especially stacks and collector rings of some motors with turbo-superchargers These tests included the following (a) a flame-impingement test, (b) three types of thermal shock test, (c) a test for the protection of the metal against oxidation, (d) a test for the protection of the metal against changes in properties caused by heating The flame-impingement and thermal shock tests caused cracks in varying degrees in all the conventional type coatings and also produced reboiling in these coatings during the heating The coatings showing the least reboil gave the best protection to the metal against oxidation, and also proved most effective in preventing loss in strength and the development of embrittlement.

A considerable number of exhaust stacks and collector type exhaust systems, coated at the National Bureau of Standards, were attached to motors and tested by the Army, the Navy, and several aircraft companies All of these service tests showed the newly developed coatings to be superior to the conventional glossy coatings. In no case did the former develop visible cracks or reboiling

Commercial production of low-carbon steel exhaust stacks with NBS ceramic coating A-19 (applied in one coat) was started in 1944 By the end of the war three porcelain enameling companies had applied the coating to substantial quantities of aircraft exhaust stacks. Since the shortage of stainless steel never became acute enough to limit its use in aircraft, the A-19 coating on low-carbon steel was used through preference rather than through an enforced substitution. Another application of the A-19 coating which reached the production stage before the end of the war was the coating of tail pipes for the exhaust systems of the amphibious truck or "DUC" These pipes were originally fabricated of uncoated low-carbon steel and failed rapidly in service, owing to corrosion. Not only high operating temperatures, but also contact with ocean water contributed to the corrosion. Tests showed that coating A-19 provided good protection.

In addition to the use of the new coatings for the protection of low-carbon steel in various military exhaust systems, there are a number of other possible applications where the new coatings (or modifications thereof) might be beneficial in prolonging the life of steel parts which are subjected to relatively severe temperature conditions Such potential applications might include the following domestic stove parts, such as grates or burners, industrial furnace parts, such as muffles, dampers or burners, parts for heat interchangers, heat baffles for continuous porcelain enameling furnaces, annealing boxes, and mufflers and tail pipes

ANALYSIS OF CERAMIC MATERIALS

The Bureau of Mines conducted a large number of research projects on various ceramic materials during 1946 and the early months of 1947 There appears an extensive compilation of these projects, arranged alphabetically by the different research laboratories of the Bureau, in the *American Ceramic Society Bulletin*, June 15, 1947, p 194-6

A multiple fellowship is being conducted at the Ohio State University Engineering Experiment Station on the utilization of spodumene in ceramic bodies This work has been done in the laboratory, and plant trials have been run at five or six potteries fabricating underglaze decoration in domestic and hotel-china grades The spodumene was tried out in additions mounting to from 10 to 40 per cent of the added flux The effect of fading of the colors was exhaustively studied The bodies were compounded, tested in the laboratory, and in plant practice in semiporcelain and sanitary porcelain bodies These bodies are now being proved in several industrial plants The use of spodumene as a constitutent in a multiple flux to produce a low-temperature porcelain is being studied

The properties of natural aluntic clays were investigated It was found that alunite raises the softening temperature of clays but there is a limit beyond which it acts as an energetic flux The presence of alunite was observed to cause secondary expansion in reheating at temperatures higher than the original firing temperature The effects of adding alunite to refractory clays were also studied In general, small quantities (not exceeding 20 per cent) of alunite improved fired characteristics, including decreasing the reheat shrinkage and increasing the P. C E Excessive additions of alunite, particularly to the low-grade clays, caused bloating as a result of the evolution of sulfur gas from the alunite.

An investigation of some Missouri clays and shales was recently completed by the Missouri School of Mines and Metallurgy in cooperation with the Missouri Geological Survey. Although many of the shales and clays of Missouri have in the past been or are presently being used for the manufacture of heavy clay products such as facebrick, common brick, sewer pipe and tile, there is in these postwar years a significant shortage of these products within the state and country. The clay and accessory minerals in each clay and shale were determined by the differential thermal analysis and petrographic methods, grain and particle-size distribution were ascertained by the screen-analysis and water-elutriation methods Attempts are being made to correlate the plastic properties with the amount of colloidal material, type of clay mineral, and the non-plastics present. The ceramic properties of the clays of the Polo gas field in Missouri have also been investigated in cooperation with the Missouri Geological Survey

Illite, montmorillonite, halloysite, and volcanic ash have been investigated as whiteware body ingredients These materials can be employed to increase plasticity. Montmorillonite was found to give the higher plasticity, but it may cause difficulties in casting, owing to its thixotropic quality Illite increased the plasticity without increasing the shrinkage or damaging the casting properties of slips, and small additions gave a workability similar to ball clays

GLASS

Basic Research

The amount of effort being expended both in basic research in the field of glass and in development work pertaining to the glass industries is probably greater than ever before In basic research the subject of the constitution of glass is receiving much attention, earlier and fundamental X-ray studies are being supplemented continually by interpretations of changes undergone by glass at moderately elevated temperatures. Efforts are being made to relate such observed changes to constitution studies Extensive inquiries have also been made into fatigue glass under static load and the effects of water and temperature on the strength of glass rods.

The practical glass problems taken under consideration since the end of the war are almost too numerous to mention Those discussed briefly below may be regarded as being foremost among the notable accomplishments in recent development research

Glass Fibers

Attempts have been made for more than fifty years to produce glass fibers that would be fine and pliable, but this material was not transparent and could not be creased or folded Fibers developed at the turn of the century were finer, but it was still too coarse for weaving practical fabrics About fifteen years ago real prog-

Interior of porcelain enameling plant, showing drying ovens, of C.A.T.I.T.A. in Buenos Aires, Argentina.

ress in this direction became evident, and today commercially useful fibers and applications for them are multiplying very rapidly

Flexibility is the one outstanding characteristic which distinguishes these fibers from all previous forms of glass This is the result of their being drawn incredibly thin in proportion to their length They possess remarkable dimensional and physical stability, thus eliminating shrinkage, swelling, or stretching The fibers will not rot or oxidize, and are unaffected by weak alkalis or by acids in their most concentrated form—except hydrofluoric and phosphoric

One of the most interesting developments in the fiber glass field is the *wool* Extremely light in weight, it is particularly useful for thermal insulation, or for further fabrication into blankets During the war this same material was employed for the control of sound as well as heat, and thus the basis was provided for its wide use as acoustical insulation—by such industries as motion pictures, radio and television

The unusual combination of properties possessed by glass fibers has led to its successful invasion of the field of medicine They are non-toxic, non-allergenic, and produce no harmful effect upon human tissue Among the many uses being found for the fibers in medical work are fracture casts made of a fabric knitted of glass-fiber yarns combined with cellulose acetate yarns Having permanence of dimension, the glass prevents creepage and shrinkage of the cast while setting, thus preventing painful constriction of the injured person.

Superfine glass fibers, treated with a water-repellent substance, are finding postwar uses as linings for mittens, hunting jackets, and other outdoor clothing for children and adults If certain fabrication problems can be worked out, the superfine fibers should also be useful for comforters

It is by no means inconceivable that glass may some day be used on automobile fenders The United States Patent Office recently revealed that an automotive manufacturer is considering a molded automobile fender of glass fiber and plastics, as a replacement part for models no longer being made because the dies are not available Such a fender would be lighter and could be produced at lower cost

Refrigerator liners receive the ground coat in a dipping application.

Infra-red may be used for continuous applications as when pottery is passed on conveyor through oven.

Glass-Metal Seals

Considerable advances have been made on the subject of "matching properties" of metals and glasses used in making glass-metal seals New methods have been developed for metallizing glass articles which are to be soldered or welded to metal parts In addition, there have been significant improvements in the manufacture of graded seals, using low expansion glasses

Glass surfaces have been modified by coatings and by chemical treatment, both to increase and to decrease surface reflectance Water-repellent coatings for glass have been developed and electrically conducting coatings have been produced for application to glass surfaces

The flow and movement of glass in tanks has been studied by observation of the travel of fluorescent materials added to the molten glass Coloring materials have also been added for the same purpose, and color changes have been noted by colored photographs The close control of the density of tank glass has been found to be a good means of aiding in quality control The development of apparatus for making accurate rapid measurements of density has been largely responsible

Inelastic Deformability

Research workers at the National Bureau of Standards have reported on the relation between inelastic deformability and thermal expansion of glass The properties of a glass are affected not only by changes in the actual temperature but also by changes in the equilibrium temperature. A glass contracts and evolves heat when equilibrium is approached from a superheated condition The rates at which these heat effects develop depend on the rate at which the difference between actual and equilibrium temperatures is decreased and they are therefore controlled by the inelastic deformability. An equation was proposed that related these various rates to the inelastic deformability.

Owing to shortages of certain glassmaking raw materials, large producers of glass are expending considerable effort in trying to develop melting, refining and fabricating methods which will permit commercial use of glasses requiring less of the critical materials. The developments involved include changes in glass compositions, refractories, furnaces, and forming machines. Fuel shortages, moreover, have made it necessary to arrive at a better understanding of heat transfer, the movement of glass in tanks, and the influence of raw material properties on melting rates, in order to make the glass-melting processes more efficient in the use of natural fuels

Dielectric properties of glasses at ultra-high frequencies (3-cm and 10-cm wave lengths) have been determined in relation to their compositions Alkali ions in glasses give rise to high losses, which increase as the number of ions increases Glasses containing a combination of alkalis show lower losses than the equivalent compositions with only one alkali Divalent ions do not contribute as much to losses as alkalis, but high power factors are shown by glasses with high BaO or PbO contents Alumina increases the dielectric losses of glasses in much the same manner as other network modifiers

A study is being made at the Missouri School of Mines and Metallurgy of stannic oxide (SnO_2) in glass systems The initial phase of this study consists of the investigation of the colloidal state of SnO_2 when suspended in a media of a simple, molten glass The final phase consists of the investigation of the influence of metallic ions within the glassy media upon the stability of the SnO_2 glass system

Photo-Sensitive Glass

Perhaps the most recent and one of the most interesting developments in glass research has been that of "photo-sensitive glass"—the printing of photographs directly on glass The sensitivity of glass has long been guessed at because of changes in color noted in glass which had been exposed for centuries to the light and heat of the sun Starting with the premise that the change was due to a chemical reaction among the components of the glass, a research chemist at the Corning Glass Works was able, some years ago, to obtain several shades of color in previously crystal-clear ruby glass upon the application of ultraviolet light and subsequent heat treatment Several years later another Corning chemist was assigned the task of exploiting the photographic potentialities of the glass. His work resulted in the development of a photo-sensitive glass in which pictures may be printed which have a three-dimensional effect, due to depth of image penetration, a variety of colors, and extremely fine detail.

The ingredients that make possible the photo-sensitive glass are an integral part of the glass, having been mixed into the batch and melted There is no danger of exposure as long as no direct sunlight or ultraviolet rays strike the glass There are several types of the light-sensitive glass One type has a color range from purple, blue ruby to orange, another will develop a brilliant red a third type produces yellows and browns Only a single color can be obtained from each sheet

To print a picture on the glass, a conventional photographic negative is placed between the glass sheet and a source of ultraviolet rays in the same manner that a contact print is made Irradiation produces a positive colored print, the depth of tint depending on exposure time and other factors The color is fixed in the glass by heating the sheet in a furnace at 1000 1050 deg F. for about half an hour, so that the glass is no longer light-sensitive Color can be produced in glass sheets up to two inches thick With thick sheets, a "solid" or dimensional effect is obtained in the finished "print"

Although the glass is still in the laboratory stage, and no cost estimates have yet been released, researchers see a big future in such non-photographic uses as inexpensive stained glass new decorating techniques for glassware and containers, and lighting fixtures

Other glass researches include study of the heat transmission of glasses as affected by oxide additions, the improvement of heat-absorbing glasses, the development of hard glasses, the study of mixing factors affecting glass-batch mixing, and the use of selenium as a glass colorant

Acknowledgment is made to Elias Jones for his assistance in the preparation of the general-reference bibliography appended below

Illustrations for this chapter were obtained through the courtesy of the Ferro-Enamel Corp, Pfaudler Co, FINISH (magazine), Despatch Oven Co and Trumbull Electric Manufacturing Co

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CHAPTER XII

INDUSTRIAL DESIGN

by J. P. YOUTZ

History of the Profession

The industrial design profession is relatively new, established legally as such only in 1944, the same year the Society of Industrial Designers was created It was organized to raise the general level of industrial designing in the United States by protecting the client as well as the profession itself Its membership is limited to those of proven ability The youngest profession, *industrial design,* emphasizes the need for trained consultants to industry and points the way to a program for their education—providing men with a know-how in art, engineering, economics, and mass psychology (1) It was only after World War I that an affiliated group of artists, architects, and craftsmen in Europe even attempted an organized program of fitting the aesthetic possibilities of material to mass produced items

Initial movement towards professionalization in the United States followed from the collaboration of a few artists with several progressive manufacturers to attain a more attractive appearance for objects leaving the production line Many of these original artists were quick to learn manufacturing techniques, the properties of new materials, and the problems of manufacturing for the mass market Today they are leaders of the profession of industrial design

As early as the eighteenth century Massachusetts' industrialists promoted the value of public school drawing and design in an effort to graduate better craftsmen for industry With the dislocation of style by true design and the recognition of *function* by the artist, the American merchants, manufacturers, and business men awakened to the necessity of utilizing original designs for meeting both domestic and foreign competition

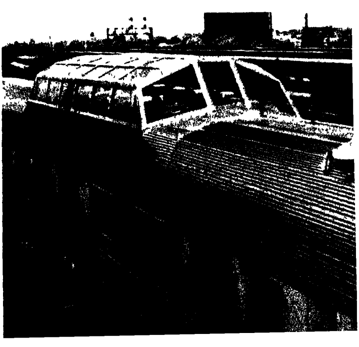
In 1922, *Nation's Business* published an article by Richard Bach, "The Museum, a Factory Annex"; and *Atlantic Monthly* in 1925 under the authorship of Ernest Elmo Calkins published "Beauty the New Business Tool." In 1928 the Metropolitan Life Insurance Company published a 44-page brochure known as *The Use of Style and Design in Industry Printers Ink* in 1929 came along with "The Glorified Cook Stove Takes a Bow," by Arthur H Little; *The Saturday Evening Post* in 1930 printed "Industrial Design," by Gilbert Seldes. *Boston Business* in 1930 published "Like it or Not, Manufacturers Must be Artists Today," by Albert Urskin, and the same year Henry Dreyfuss furnished the basis for a story about the designer in the *American Magazine* by Beverly Smith with the title, "He's Into Everything" (2).

Industrial design is simply the application of taste and logic to the products of machinery, a means of improving the product of the machine both in appearance and performance (3) The industrial designer must thoroughly consider the quality of human elements and consumer preferences This background to his design results in a more appealing, usable, and salable product As a result of the designer's intelligent use of materials, manufacturing processes, skill in color and form, the finished product is attractive because its entire production was carefully planned

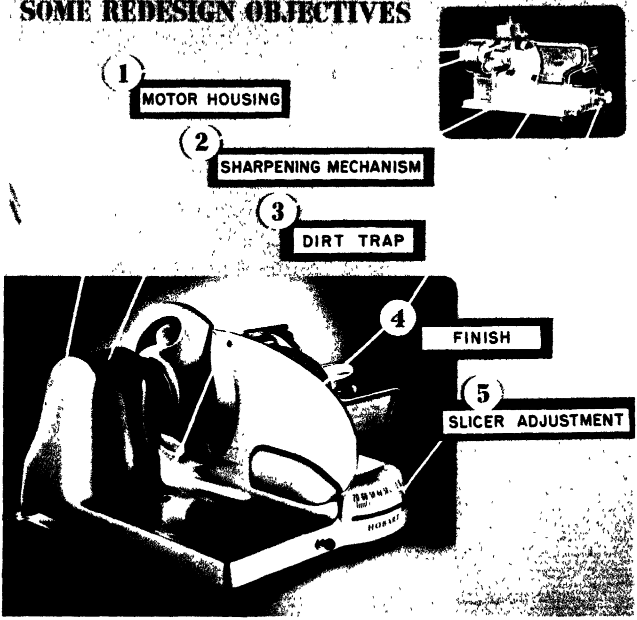
As early as 1941, the author pointed out that American industry, under the pressure of enormous production rates and low manufacturing costs, must elaborate designs that recognize the latest products of the laboratory, the tool designer, as well as the demands of modern living habits Facilities involving millions of dollars of investment and the productive ability of thousands of trained men cannot afford to guess at the popular acceptance of their products The new profession of industrial design really rests on the shoulders of the engineer, is guided by the merchandiser, while seeing with the eyes of the artist The work of the designer makes industry more productive, makes the product more attractive to a buying public and more effective for those who are to use it

Industrial design today means product development from early stages of research through production, pack-

Exterior view of Vista Dome Car on the Burlington Railroad.



SOME REDESIGN OBJECTIVES



age design, sales promotion programs and even to the point of designing the surroundings at the point of sale All forms of modern living—homes, factories and industries, stores and theatres—reflect the skills of the industrial designer.

The well-designed product, once an exception, is now demanded by the public in all of its daily contacts with the products of industry. Simplicity, functional excellence through proper selection of materials and form are no longer novelties to the consumer

The broadest possible expression of the function of the industrial designer will today include a program something like the following:

(a) *Market Research*
Carried on by Sales Department.
Purpose To evaluate competition, anticipate prospective volume of sales and locate best markets.

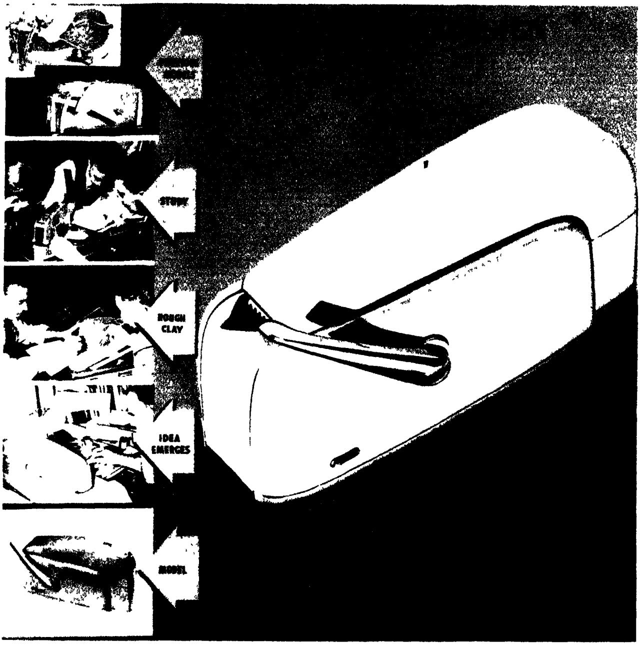
(b) *Consumer Survey*
Carried on by Sales Department under guidance of Industrial Design.
Purpose To determine popular sizes, price ranges, details of usage (such as which foods are most frequently sought, location of unit-kitchen, porch, garage, color preferences, etc)

(c) *Engineering Research*
Engineering and Research Departments.
Purpose· To study physical principles, materials, processes, etc

(d) *Conference Integrating All Facts Found*
Sales, Engineering, and Industrial Design.
Purpose: To provide a sound basic foundation for preliminary design.

(e) *Preliminary Design*
Engineering and Industrial Design.
Purpose: Formulation of basic ideas into a working design to incorporate all practical sales features advocated in research.

(f) *Conference*
Executive, Sales, Engineering and Industrial Design.



Purpose· Modification and suggestions on preliminary design.

(g) *Layout Drawings*
Engineering and Industrial Design
Purpose· Completion of mechanical design, development of basic form, specification of hardware, trim, and finishes.

(h) *Detail Drawings*
Engineering
Purpose: Preparation of production drawings.

(i) *Cost Estimates*
Engineering.

(j) *Working Model*
Engineering.

(k) *Presentation Drawings*
Industrial Design.

(l) *Full Scale Appearance Model*
Industrial Design.

(m) *Conference*
Executive, Sales, Engineering and Industrial Design

(n) *Pilot Production Model*
Engineering and Industrial Design

(o) *Design Modification or Changes*
Engineering

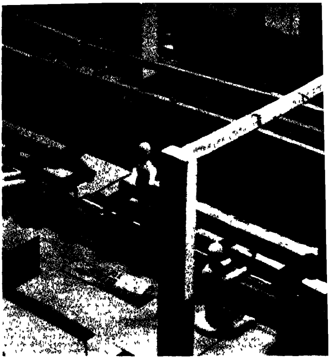
(p) *Final Product*

Through these steps the consumer successively gains functional improvements, lower costs, and distinctive appearance based on functional requirements, combined with the logical use of materials and manufacturing processes (4).

The War and Industrial Design

"We in Britain . designers, producers and consumers, are still way down in the slough of official austerity—our days unlightened by so much as a glimpse of the products which we really are capable of pro-

DRAFTSMAN draws, and designs and scales the models which will will be turned into wood.



MODEL WORKERS attach axles to frames and install hydraulic lines in trucks.

CRAFTSMAN puts finishing touches to model trucks and cars in Ford laboratory.

PRODUCTION ENGINEER points out model for plant at Ford's Highland Park.

ducing (unless it be a swift-passing 'export only' flash) . For—and make no mistake about it—when the creative brains of this old land are really freed from the cramping hand of bureaucracy, we will once again be making a worthwhile contribution to better living, to a more gracious living, a finer contribution than we ever made before" (5)

The only work worthy of human beings is the doing and making of things, tangible and intangible, that satisfy the worker's own needs and desires, and the desires and needs of other people In a society as complex as ours, work calls for the application of ingenuity and energy by a host of specialized individuals The forces operating to create the demand for a product are almost infinitely intricate, far too complex to be comprehended in their entirety by even a group of minds, and impossible to direct from any central source When we reject directed, bureaucratic controls, a managed economy, "made work," the appalling version of "freedom" offered in Sir William Beveridge's counsels of despair, we are doing two things we are refusing to let our wants and desires be interpreted or be satisfied according to a ration book As a people we have tremendous unsatisfied needs And it appears that these needs are indefinitely expansible We have the means —material, scientific, and technological—to satisfy these potential demands From all past and present evidence, resources in all three categories will continue to expand as rapidly as we can make use of them (6).

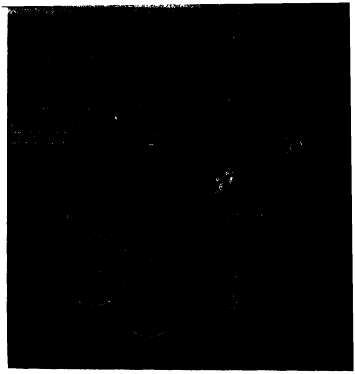
The peculiar pressures of war have brought changes of technique, materials, and methods of building, changes which are not all new but new in their intensity Already an enlightened social conscience has been reflected in a better standard of equipment (7)

During the war many new, more efficient types of tool were evolved for the use of the engineer In every branch of tool-making, improvements are being employed by industry with a view to the greater efficiency and more agreeable appearance of the product These qualities invariably go together, as they should in good design If a tool looks and feels right, it usually is right If it looks clumsy and is ungainly, it almost certainly needs redesigning For example, the table knife of today is being made much lighter The blade is tapered and shapely, and the handle slender and more comfortable to manipulate It cuts well, feels well, and looks well That is a long way on the road to good design, but not all the way Ease of cleaning, fine finish and beautiful materials should all contribute their share to the design and production of the perfect knife (8)

Post-War Design Plans and Dreams

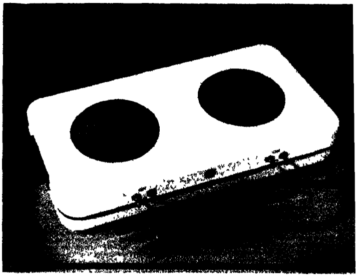
The impact of the profession of industrial design on the field of architecture is a logical trend represented by architects actively participating in design problems which frequently included exhibits, displays, and even packaging. Henry Dreyfuss, in cooperation with Edward L Barnes, an architect, developed a pre-fab house for the clamoring G I and proof of its freedom from the dream element was its consideration by the Consolidated Vultee Aircraft as a possible outlet for released war-time production capacity in the aviation industry (9).

The consultant on design is a clearing house of ideas related to all phases of the product including production, sales, and use The new role of industrial design combines engineering with functional styling. The best outlet for additional applications of the work of the skilled consultant is today among small manufacturers and firms with new or auxiliary lines This was emphasized at the recent exhibit of the Society of Industrial Designers, which was notable for its absence of futuristic drawings of idealized products, and for the presentation of products now awaiting release by recognized manufacturers (10)



This design for a two burner electric hot plate had to be outstanding in a highly competitive market, while meeting the existing production facilities and skills of the manufacturer. Since stamping presses with a maximum draw of 1⅝ in. were available, all possible elements of the product were designed for this method of fabrication.

This is the finished product as designed by Benjamin L. Webster for the General Aviation Equipment Company. The final design was chosen by careful test from several alternates.

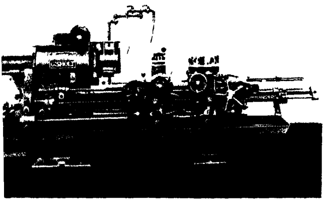


The profession of industrial design has expanded until individual firms now maintain offices throughout the world with hundreds of employees and a monthly payroll closely approaching the six figure value The industrial design profession represents a 25 million dollar business divided among 500 or more industrial design specialists.

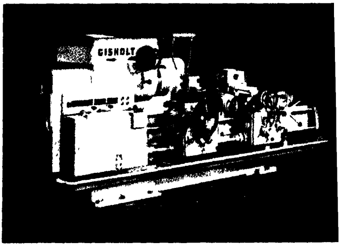
Modern steamships, buildings, tractors, and railway cars owe their comfort and efficiency as well as their more attractive appearance to the work of the professional industrial designer Dining cars that look like a group of rooms rather than a long corridor, modern towns in the interior of Brazil, and aircraft with the appointments of the finest luxury cruise ships are the products of experts in the use of color and the psychology of consumer reactions Specialists in merchandising, industrial designers build the impressions of solid security into aircraft cabins, lightness and speed into railway coaches, warmth and comfort into aircraft flying near the arctics, coolness in the planes of the tropics, luxury at the low-priced dining counter, and will put your favorite color in the tooth brush handle to make it sell itself to you (11)

Post-War Designs

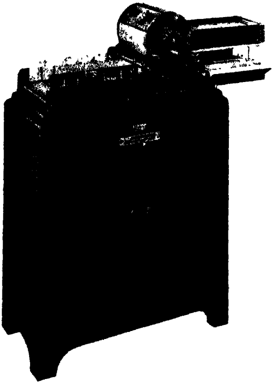
Post-war production, which had attracted the export



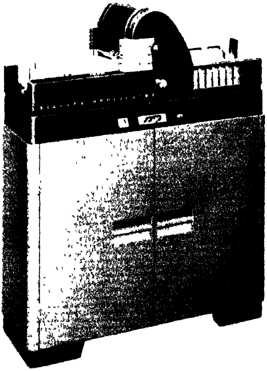
Gisholt turret lathe before redesign had protruding forms and separate housings secured to machine.



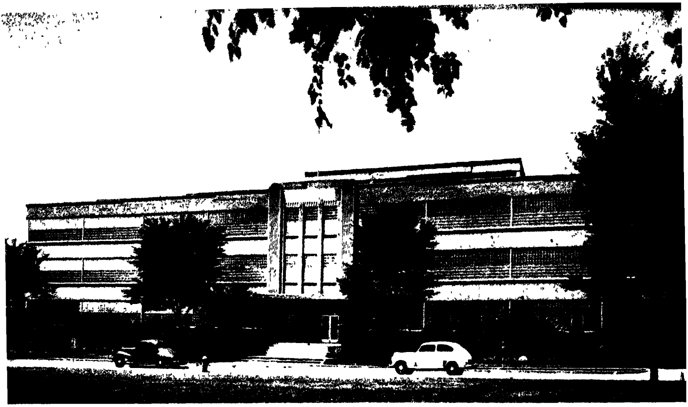
Redesign gave simplification of mass and accessibility of controls for improved efficiency and appearance.



The Niagara Duplicator before the machine was redesigned to combine better engineering with functional styling.



New Niagara Duplicator, a truly post-war product, assures manufacturing economies and improved product performance.



Miles Laboratories at Elkhart, Ind., is an excellent example of modern industrial building design. It is built with non-glare and light-directional (prismatic) block, and is completely air conditioned.

buyer, has drawn attention to the need for new and original designs This trend, for example, is shown in the post-war office machines They represent completely new designs, technically improved by the inclusion of new features However, their utilitarian appearance is obviously the great improvement This general improvement may be seen specifically in typewriters Besides being lighter, and easier to operate, because of mechanical improvements and the increased use of light alloy sheet combined with die castings, they follow the modern trend with working parts completely enclosed (12)

Design is a fundamental sales tool but it must also be closely linked with the various divisions of manufacture When a product fails it may fail for a variety of reasons including poor engineering, production inefficiency, inadequate distribution, etc A well designed product capable of facing competition requires good engineering, adequate manufacturing facilities, efficient methods of production, sufficient capital reserves, competent sales direction, well-organized distribution, competitive prices with adequate margin to distributors The master link in coordinating these activities continues to be increasingly important and centers in the design and engineering of the product (13).

The post-war market is being met by a redesigned line of products affording the necessary step-up from model to model without unnecessarily burdening the entire line with too many units Concentration of as high as 96 per cent of the output on a single group of models greatly reduces production costs and retail prices.

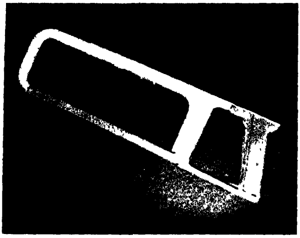
The American public is generally well educated to good design, and the design must always be recognized as a factor whether the product is new or not. In the case of well accepted products, the designer's part becomes more difficult and still more important. Well accepted products seldom permit radical changes; and refinements of basic style become an important selling point Rapid, sweeping changes in design are frequently poorly received by the public as well as costly to the producer through obsolescence of tools and dies.

Poor or obsolescent design depresses the turnover of used appliances and injures the retailer's profits In a competitive market, value must constantly be boosted, the product must continuously become more convenient to use, more attractive, and sell at a relatively lower cost (14)

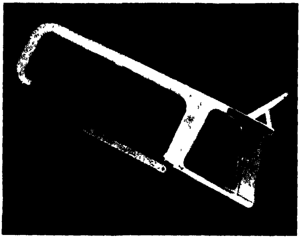
Substantial economies in production and assembly plus added sales appeal result from an analytical approach to redesign for a product involving safety and long life while allowing rough treatment, ease in tooling, and high production rates (15).

Faced with a satisfactory product made by old manufacturing techniques at a cost of manufacture too high for post-war market, one redesign considered function and appearance simultaneously with mechanical changes, new manufacturing processes and materials, greater volume production, ruggedness with smooth appearance The resulting product, the Niagara Duplicator, is a fine example of meeting competition before it really begins to be felt at the sales level It represents the production of a truly post-war product with manufacturing economies and improved performance designed into the product from the very start.

The principal materials for the construction of luggage have for centuries been wood and leather, often in combination The first major change in heavy luggage was brought about by the use of fibreboard covered with canvas In recent years fibre has been largely replaced by thin plywood Developments in light metal alloys are now providing further opportunities for the construction of light-weight luggage. Other suitable materials include the so-called leather-cloths (cotton fabrics coated with nitro-cellulose or polyvinyl-chloride), and cotton duck impregnated with resins (16, 17).



Collura's design provides automatic tension and thumb control.



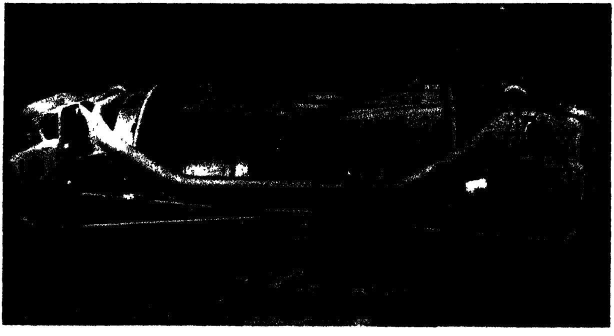
A hack saw frame, designed by Francesco Collura, New York designer.

Francesco Collura's iron and cooker for General Mills, Dave Chapman's collaboration with National Sewing Machine Company for the improved design for Montgomery Ward & Company, and the integrated operations of such nationally famous designers as Walter Dorwin Teague, Harold Van Doren, Henry Dreyfuss, and Raymond Loewy—to name a few—offer their clients, market analysts, architects, engineers, draftsmen, model makers, and machinists (10, 19)

The President of the Studebaker Corporation in his address before the conference of The Society of Industrial Designers on October 15, 1947, expressed his opinion as follows "Willingness to buy or 'discretionary spending power' as contrasted to 'necessity buying' plus new products that are both better and better looking . . . create dissatisfaction with what we now have and keep our economy functioning at a high level."

An example of modern design abetted by post-war shortages and the resulting seller's market provides a unique module mechanism for flexible, mass produced structures These are largely completed at the factory where precision tools and superior workmanship are available Such new designs in various products get their opportunity for acceptance today because of shortages in sources of supply Finished articles are produced according to a module plan without any restrictions on size It is a daring concept given great stimulus in the present urgent need for large quantities of housing or furnishings with the minimum quantity of inefficient, high cost labor and scarce or unsuited materials Quality control, precision machinery, and quantity production under factory conditions of mass production produce a wide diversity of modern housing units ready for field assembly (18).

One manufacturer of steel products sold to the automotive trade hesitates to adopt a new design made of



In torsion suspended truck, built-up tension is harnessed to make rod serve as a spring. Although previously used on automobiles and truck trailers, it has been redesigned for use on railroads.

metal because of the critical position of the new users of sheet steel and the possibility that new designs will involve other materials such as plastics Railway equipment, except in the case of a top ranking company operating with a high percentage of its own equipment, has been slow to reveal designs which have been off the designer's board for more than a year This is partly due to the high priority given freight equipment and partly because of the fluid position of the control and management of many of the roads at the moment These two factors are now being resolved to permit going ahead with ideas such as incorporated in the "Train of Tomorrow" Fair trading and other regulatory trade practices have also reduced the competitive urge to launch new designs

The Need for Fundamental Redesign

As the architect and the structural engineer create a modern building so must the skills of the artist and the engineer be combined if modern products are to meet current popular needs The product of their design must work satisfactorily without constant and complicated adjustment or repair, it must be adaptable to the machines and materials available for its manufacture, it must be made easily and inexpensively, and above all it must appear to have value in excess of its cost when judged by the customer for whom it was designed In other words it must look desirable and tell its story so that its value will be recognized in the market

Twenty years ago the consumer was not conscious of industrial design and seldom found good design in the product About ten years ago industry began to notice that articles possessing suitable design attracted more sales. Today the consumer expects and insists upon good design (24).

The skill of the designer is expanded immeasurably by mass production, new materials and world-wide distribution Beautiful new things are now no longer regarded as a privilege of the very wealthy Art is no longer the product of a few

Lawn mowers, office equipment and domestic labor saving devices are beautiful but they incorporate a harmonious design that permits them also to work more efficiently The struggle for the public's approval through an appeal to the eye affects the decision that controls the pocketbook, all the way from the beauty shop to the machine tool industry.

The industrial stylist and artist are yielding their place to the industrial design engineer who works with the staff necessary for handling everything from the production schedule to the distribution plans Eye appeal means something more than *new*. It represents a personality for the product, an indication of its abilities, and the skill which has gone into its production; in fact, it should be a graphic and accurate expression of true value.

Appearance as an indication of proper design is no longer an effect created by a product's slow evolution in the hands of craftsmen trained through a long apprenticeship. Developments now proceed at a rate which demands professional designers who are experienced in or at least can quickly learn the production operations involved in today's manufacturing system

The industrial designer works in close cooperation with the experienced draftsman-designer and production engineer from the earliest stages of the design Compromises for beauty and function disappear into an integrated design which focuses attention on the product's ability to perform It gains beauty from the perfection of its successfully completed design It should always form a part of the developed product. The organization of the parts in the machine should be achieved in exactly the same manner that the artist, the sculptor, and the stage designer develop their most successful designs, starting with the selection of materials, colors, dimensions, and their organization

Simplification has done much to improve the appearance of modern products and the much abused term of streamlining is gradually being restricted to those applications where dynamics are truly involved Improved die casting, injection molding of plastics, sheet-metal forming, and welding are all providing means for greater economy, more efficient use of material, the elimination of unessential frills, and the production of much cleaner, functional machines Nevertheless, the consumer will not accept over-simplified, severely plain articles when the availability of materials permits the slightly more decorative model In many instances this affords the merchandising men with their much desired and reasonably priced deluxe and standard models

Compact but attractive powder room on railroad coach appeals to feminine passengers.

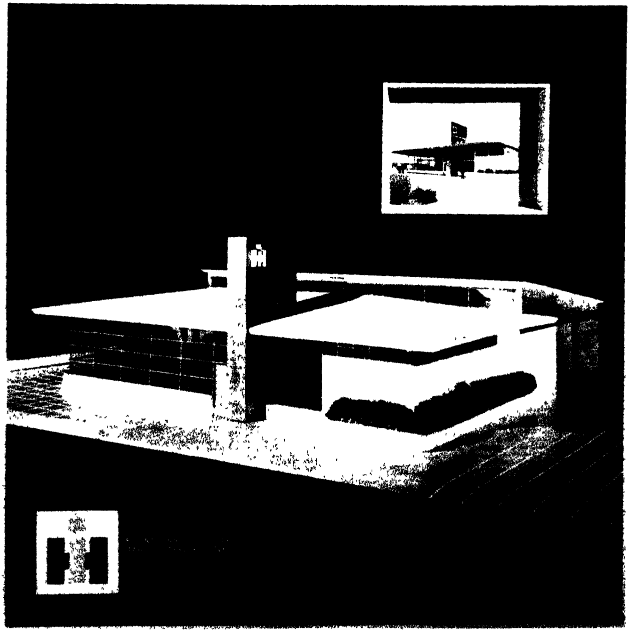
The trend, however, seems to be toward more emphasis on the achievement of beauty in design through a careful study of proportional relationships and the proper use of materials rather than by a superficial application of traditional art forms, added areas of chrome plate, and other similar stylized factors Each design becomes a new measure of the designer's ability and can only be an approach to a theoretical ideal

The designer must be well-informed in those fields of science and engineering which relate to the cost of materials, the cost of manufacture, the cost of distribution, and the present trend in the field of economics He must have a definite aptitude for aesthetic and basic design as well as a real ability to evaluate current published literature in his fields He must be logical, analytical, and have an organized design program which distinguishes between the essential and the irrelevant

Designs must be human because they are not only created, but used and appreciated by every type of person (20)

Machine styling must be related to the useful life of the item so that it does not become obviously dated before a reasonable percentage of that life has been utilized Hence, office, scientific, and industrial equipment generally must represent a more conservative approach Eye-catchers on the sales floor might very soon become eyesores in the factory, office, or home Good aesthetic judgment is indispensable to satisfactory design The basic form, its utility, safety of operation, maintenance, cost, materials used, and the means of its fabrication all represent steps in obtaining the final unity of design Qualities of style to be evaluated in any product development may be summarized as follows

A standard dealer outlet designed by Raymond Loewy for International Harvester.



- (a) *Unity*
    - (a) Simplification of Form
    - (b) Proportional Relationships
    - (c) Repetition
- (b) *Interest*
    - (a) Emphasis
    - (b) Contrast
    - (c) Rhythm
- (c) *Balance—Further Enhancement of Basic Form Through Surface Treatment*
    - (a) Color
    - (b) Texture
    - (c) Quality

The manufacturers faced in a competitive market with problems of appearance are recognizing the public demand when they employ the services of an experienced industrial designer He is charged with the responsibility of analyzing the very reason for the existence of the product and its function He attempts to design the product to sell itself through its obvious ability to perform its functions and to appeal to the pride of ownership, at a price which the greatest possible number can well afford (21)

In a crowded market the industrial designer must carefully evaluate competitive products and pay close attention to their engineering and functions The development of a cigarette case and lighter provides a good example to illustrate this point Beginning with the market analysis to determine the salient features to be incorporated in the product, a combination cigarette case and lighter was developed offering lightweight, the capacity of holding a full package of cigarettes and two weeks' fuel supply, convenient use and simplicity of design in both appearance and function A lighter which will light almost a carton of cigarettes on one filling, easily filled and easily maintained, is ready for a competitive market because the designer has considered not only the user's needs but also the manufacturer's production requirements Thus the industrial designer is constantly performing his function of liaison to reconcile low cost products with the public demand for beauty, simplicity, and dependable performance, using the latest knowledge in technical products and engineering materials (22)

Sales and Product Engineering

The design engineer is responsible for integrating the policies and company objectives with the product's design Thus he may broaden his perspective and take on new responsibilities in the measure that he appreciates the need for better and cheaper processes. Redesigning for simply the pleasure of having a new product must give way to designs for higher qualities or for lower prices A seller's market in the face of material shortages and the difficulties of reconversion tends to increase costs and result in inferior quality This means that design improvements should generally avoid excessive changes, at least those which would result in unjustified increases in costs due to tooling. The best design is frequently the one which permits continued large scale production of a few basic units forming a complete line of products. If the original design is fundamentally sound, new features can be incorporated which will provide added sales appeal without greatly increasing the manufacturing cost

Designs must obviously be fitted to the position of the company in its particular field as well as to the field itself This means close cooperation with sales and management as well as with the production division It should be based upon and take full advantage of the knowledge of current market conditions and current customer reactions Designs should look ahead and yet should not be so far removed from present conditions as to make them incompatible with the needs of the consumer A seller's market has appeared in the picture because of shortages of sufficient suitable materials for manufacture Successful designs must be adjusted to the materials available at a reasonable cost The production division can ruin a good design by faulty manufacture, but a poor design cannot be made successful by all the efforts of the manufacturing division, the inspection division, or the sales division, who though they may fail to get the most out of good design, cannot alone make a poor design successful The design engineer should be able to take the responsibility of leadership in guiding the planning of many company operations (23)

A non-technical public is first impressed by a pleasing, distinctive appearance It appreciates performance qualities only after a period of use Mass-produced consumer goods require the services of an engineer with taste and a flair for merchandising (New materials dictate new forms, new combinations, new finishes, and impose new limitations) New and beautiful materials overcome sales resistances, appeal to public taste, and take advantage of a coordination of market surveys, technical knowledge, and merchandising practices to make a product sell over its competition

With the re-appearance of keen competition, reduced costs to the consumer are essential, but not at the ex-

To achieve the economies of modular coordination, 4 x 8 in. face bricks were used in the construction of this factory.

This Scott-Atwater outboard motor was redesigned to improve its function, appearance and acceptability. Its modern design depends upon smooth, functional shape rather than superficial ornamentation.

To compete pricewise, this low-cost product provides beauty, simplicity and dependable performance.

pense of performance or appearance. The designer must never price the product out of the market. The design must be tailored to fit the existing situation in the client's plant, the plant can not be tailored to fit the design. Cleaning up a product not only improves its appearance but lowers cost, while useless ornament produces a "busy" and hard to clean, often expensive product. Good design depends upon smooth, functional shapes rather than superficial lines or ornamentation.

Different price levels in a line of products must be apparent by the exteriors. The basic model must be complete in itself, and the higher cost items should look their part although enjoying the same basic design—all without looking overdone (24).

Every manufacturer who places products before the public for sale must keep foremost in his mind the need for public acceptance of his product. In addition to public taste, the manufacturer must consider availability and cost of materials, cost of manufacturing the product as designed, and the fact that no element of basic utility has been sacrificed for the sake of design. Manufacturers' requirements for a wide variety of metals and alloys to satisfy the product's design and engineering demands are resulting in more new raw materials and methods. If materials are not immediately available which will permit manufacture of the product as designed, or if the cost of such materials and the machines necessary to shape these materials is prohibitive, the design of the product must be altered (25).

Each piece of equipment, each tool, each device and appliance should serve its specific purpose, honestly and fairly, in appearance as in performance. Out of the multiplicity of services devoted to a product's creation will come the visual unity and purposefulness that makes the product a pleasure to see and use (26).

A step by step study of carton design, for example, includes the elements of consumer interest and sales stimulus: choice of overall design, variation of the design for emphasis of certain elements, refinement of the completed design including color, layout, topography (27).

We are advised that industrial design is the application of art to mass production. Merchandising combines consumer research with the economic means of filling the public's wants. Their common goal is to increase sales and profits through the improvement of the function, appearance, and acceptability of the product (28, 30). Design for appearance and wide public acceptance mass production and function afford an example of the tie-in between advertising, sales promotion, equipment design, and consumer attitudes. An incidental by-product of overall planning is the favorable employee reaction to the influence of the industrial designer in plant layout with increased emphasis on good lighting, and good color schemes (29).

The Growth of a New Profession

Heretofore, most stores have been designed by architects. Without intending to reflect upon the talents and abilities of architects we wish to point out that an architect, when he undertakes to work out the plans for a store, does not usually start from a merchandising point of view The architect usually thinks in terms of traditional architecture He has studied Greek Architecture, Gothic Architecture, Renaissance Architecture, cornices, columns and all ancient architectural forms. Because of this background of education he usually thinks in terms of creating an edifice instead of designing a machine for selling, when he plans a store

A designer is hampered by no such traditions He is functionally minded He is trained to think first of the use of the thing he is to design, not its traditions It is reasonably accurate to say that he habitually approaches any designing problem from a merchandising point of view

In designing an item of commerce, a machine, a package, the designer asks himself a number of practical questions What is it intended to do? Will it work? Is it commercially competitive? Will it sell?

He also asks himself the question What is its aesthetic relationship to its surroundings, to its uses, to its users? (29, 30)

The education of the industrial designer through a curricular approach to the graphic and plastic arts, as part of a legitimate profession, is still relatively new and anything but general among the institutions offering training in that field Such training, organized to demand from the student a minimum level of proficiency, is generally lacking from the arts of the schools.

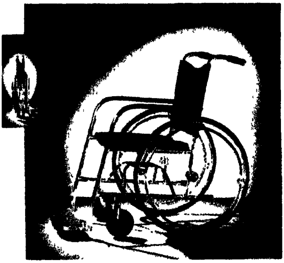
The interpretive art of industrial design is suffering from too arbitrary and subjective terminology, with particular theories becoming creeds Generally speaking, current literature can be considered as sterile of any creative thinking

The Bauhaus approach lacked in the beginning and still lacks compactness and basic integration It represents a lengthy and pragmatic argument of experimentation for experimentation's sake Function alone cannot give birth to aesthetic expression which is an expression of a given time The aesthetic reactions are expressed in a specific form which in turn influences men

At one of the leading Eastern schools of design the first year of a three-year course has eliminated every trace of practicality in the problems assigned to students It stresses abstract conceptions and inner com-

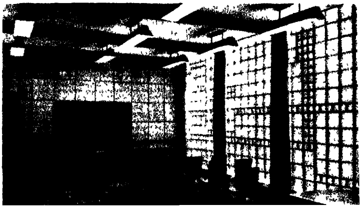
The design of this modern railway coach interior features special reclining seats.

Design of facsimile broadcast equipment assures easy readability of script.



Wheel chair combines maximum utility with attractive appearance. Its light weight and tubular construction provides mobility without fatigue.

Testing and development laboratory of Benjamin Electric Mfg Co houses this triple-utility conference room. It is used for engineering and sales conferences and for community meetings.



pulsions, experiments in creative expression rather than in techniques The word "design" has been defined as a creative intent expressed graphically or plastically in terms of materials and processes, conditioned by a functional purpose even when purely aesthetic in its nature, an idea capable of graphic materialization

According to the Harvard Report, "the aesthetic concept is inseparable from its material embodiment" The component elements of this material embodiment are (a) line, (b) plane or surface, (c) positive or negative space, (d) values of light and dark, (e) texture, (f) color—all concrete elements available to the designer

The designer is taught to recognize that "More often than not his is not a creative expression of an emotional origin based on personal aesthetic impacts it may not even be in a specific branch of expression or industry" The student is introduced to marketing problems, consumer problems, the relationship of production problems, distribution problems, packaging and transportation management The student is constantly reminded that function is an expression of a mode of living It involves the study and knowledge of materials, processes, machines Actual instruction in industrial design introduces the student to product development (32)

The essential responsibilities of industrial designers are social and creative which, if he fulfills them, make him a professional man Four characteristics are indispensable to a successful designer sensibility, creativeness, social responsibility, aesthetic awareness (33) Design education is a process wherein the student is taught to increase and integrate his own awareness, his response to materials, to processes, to human needs and desires

Conclusion

The meaning of the term "industrial design" implies *organization* It is basically the external organization of products to improve their efficiency in manufacture, in performance, in use Efficiency in manufacture is adaptation to the production processes and materials, resulting in lower cost of manufacture Efficiency in performance is functional excellence Efficiency in use is practicality combined with beauty which commends admiration for the redesigned product The industrial designer's services concern new manufacturing processes, new materials applicable to products, use of expanded equipment, new markets, future competition, company improvements in products and buildings

During the reconstruction-period horizon ahead it is estimated that $25 000,000,000 will be used in "redesigning" production industrial plants alone (35) In 1948 there can be no question as to the important and vital place of the American designer in the economic and utilitarian world of today and tomorrow (2)

America is today only on the threshold of genuine product design (25)

Illustrations for this chapter were obtained through the courtesy of the Society of Industrial Designers, Egmont Arens, J M Little & Associates, Francesco Collura, Walter Dorwin Teague, Benjamin L Webster, Henry Dreyfuss, Raymond Loewy Associates, John Gordon Rideout, Niagara Duplicator, Ford News Bureau, American Car and Foundry Co, Chicago, Burlington & Quincy Railroad, The American Welding & Manufacturing Co, Benjamin Electric Manufacturing Co, Owens-Illinois Glass Co, and American Standards Association

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CHAPTER XIII

INDUSTRIAL ILLUMINATION

by C. L. CROUCH

Light is the tool by which man's skills are brought to bear upon the tasks involved in the production of the various goods to meet his many needs Constant progress is being made to produce and convey light in sufficient quantity and with suitable quality to permit the worker to perform his tasks with facility and comfort New light sources with higher efficiency, longer life and greater diffusion, and new techniques of light control, are ever stimulating and making easier the accomplishment of the objective

Quantity of Light

Illuminating Engineering is unique in as much as it deals with human vision Continuing studies are establishing the relationship of light and the ability to see according to the characteristics of the task, namely, size, contrast and the time for perception (1 4) While these studies point toward optimum levels of illumination, it has been necessary to compromise according to the economic ability to incorporate lighting in present interiors and arrive at practical recommendations (5-7)

Quality of Lighting

The amount of light on the task is only a part of lighting The brightness of the surrounding environment completes a partnership Lighting fails if either is lacking While light meters testify to the availability of light on the tasks of today, both visual comfort and performance demand that special emphasis be placed upon the environment and its relationship to the work We are largely creatures of our environment which conditions our morale and our response to everyday tasks (2, 11, 12)

The researches and studies over the years have recently been boiled down into the following rules (9, 13)

> *Seeing is best when there is a minimum difference in brightness between the task and other parts of the environment The variation can be 3 to 1 to provide nearly optimum conditions This is attainable in present day interiors Especially is it good practice to provide surfaces immediately surrounding the task whose brightness is equal to or not less than 1/3 that of the task The brightness of the immediate surroundings should never be greater than that of the task The immediate surroundings should be considered as extending out 15 deg in radius from the center of the task*

In many good practical lighting installations it has been found that after the "heads down" task and its immediate surroundings have been carefully controlled that the more remote parts of the environment involved in the "heads up" position can have higher ratios Recent formulated recommendations (6, 7) are as follows:

> *Brightness ratios for areas of appreciable size from normal viewpoints should not exceed*
>
> *3 to 1 between tasks and adjacent surroundings*
> *10 to 1 between tasks and more remote surfaces*
> *20 to 1 between luminaries (or windows) and surfaces adjacent to them*
> *40 to 1 anywhere within the normal field of view*
>
> *These ratios are recommended as maximum, reductions are generally beneficial*

These ratios can be fulfilled through a combination of higher reflectances for room and equipment finishes as well as shielded low brightness lighting fixtures The tendency in the past has been to use dark grimy unfinished or dark gray metal surfaces in the plant and dark woodwork desks and floor coverings for the offices

Color in Industry

An important factor in accomplishing the higher reflectances has been the use of color The painting of machine surfaces has served four purposes (a) increasing visibility by silhouetting the tool against its background (b) focusing attention by color contrast upon the work at hand, (c) lending interest to a pleasing environment, and (d) bringing about better housekeeping and maintenance (14-27) Study has been made to combine low brightness ratios in office interiors for optimum visual performance with suitable decoration to produce pleasing and interesting interiors (10)

Two-Year Study in Controlled Environment (12)

The Public Buildings Administration and Public Health Service conducted, with the help of the National Society for Prevention of Blindness, National Bureau of Standards, and the Faber Birren and Company, a two-year study of increased illumination and coordinated environment in the card-punching room of the Bureau of Internal Revenue The environment was treated as follows

Location	*Color*	*Reflectance*
Acoustical Ceilings	Off-white	70 per cent
Acoustical Upper Walls	Off-white	70 " "
Lower Walls (8 ft)	Blue-green	50 " "
Floor	Tan marbelized linoleum	33 " "
Card Punch Machines	Gray-green	23 " "
Desks and Tables	Gray-green	23 " "
Trim—doors and sash	Blue-green (dark)	15 " "

The maximum brightness ratio on the work and machine was 4 7 to 1 and the maximum ratio in the operator's normal field of view was 8 to 1

Despite the many uncontrollable factors (such as large proportion of more difficult tasks during the second year as compared to the first and the large personnel turnover due to post-war readjustments) the morale was greatly improved and there was in general an increase in production ranging from 37 per cent for a particular section to an overall gain of 5.5 per cent.

Daylighting

Later types of glass prism block offer more accurate control of daylight with sharper cut-off and lower brightness toward the room occupants (28, 29). The block is often installed in conjunction with a clear glass vision strip extending up to 6 feet above the floor (6).

Increased activity in post-war construction has prompted renewed interest in design and calculation data, including town planning (28-43).

Artificial Lighting

Great impetus was given during the war to the use of mercury vapor and fluorescent lamps due to approximately double efficiency and 2 to 6 times the life of filament lighting. The mercury lamps with their concentrated arc emission were used in reflector equipment in the same manner as filament lighting for accurate control of the distribution of light. They are particularly adapted to use in high mounting equipment from which the light is directed with minimum loss to the work below. They are frequently used in combination with filament lighting to improve the color quality of the typical blue-green mercury light and often twin units employing one lamp of each are mounted together on a suspension yoke.

Fluorescent lamps brought to industry the diffusion of a linear source reducing and softening the shadows inherent in concentrated sources. Since the light is emitted from the surface area of a long tube, the brightness (intensity per square inch) is relatively low, producing comfortable reflected highlights in many surfaces, contrasting greatly with the blinding brightness of exposed filament or mercury lamps and their objectionable reflections on glossy surfaces. Due to this low brightness, many of the early installations were made with the lamps exposed toward the eyes of the room occupants. This resulted in many complaints and questions (44 to 47, 51, 52, 55) in which the difficulties were attributed to harmful radiation, flicker fatigue and fatigue due to the struggle of the eye to focus sharply because of conflicting prominent wavelengths. These have been studied and it has been generally concluded that: (a) there is no harmful radiation (48, 49, 50, 53, 54), (b) that the flicker is approximately the same as that of a 40-watt incandescent filament lamp (56), and (c) that the fatigue due to conflicting prominent wavelengths would be much less than that for the Cooper Hewitt low pressure mercury lamps which were used for years without complaints in industrial plants to achieve better visibility of detail (50). Evidence points to the fact that when the fluorescent lamps were properly shielded in lighting fixtures with low brightness exposed toward the eye that complaints began to cease (46) and all agree that with proper shielding there is no harmful effect to be experienced with this type of lighting (44, 47, 48, 51, 54, 55).

Lighting Fixture Design

A study of the shielding of the RLM type of fluorescent industrial lighting fixtures showed that a simple baffle erected between the lamps of a two-lamp fixture increased the shielding angle from 13 deg. to 26 deg. (57, 58). Readily detachable eggcrate louvers are also available.

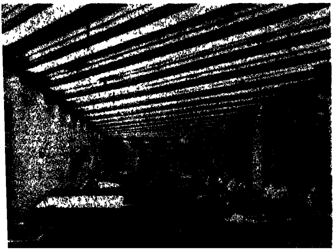
The office lighting fixtures have developed from the two- or four-lamp unshielded variety to the dense side panels and louvers type, to troffers with deep shielding, or in keeping with a recent trend to bottom diffusing and reflecting trough surfaces for semi-indirect or luminous indirect lighting (58, 59, 60, 61, 62).

Special designs for specific purposes have been developed and will be discussed in connection with the particular application.

Lamp Development

The postwar years have seen a rapid development in the use of cold cathode as well as the hot cathode lamps. The cold cathode manufacturers are making efforts toward standard interchangeable lamps to be used with reflectors in *package units* as well as catering to custom-built installations. Agreement on an 84-inch length from end to end has been made in the United States which compares with standard 8 ft. 9 in. and 7

Fluorescent luminaires providing more than 80 foot-candles are rotated 45° to tables to minimize shadows.



Grid system fluorescent light for machine shop produces broad highlights for reading dials and micrometers.

ft. 9 in tubes in Australia Longer life with lower brightness and lower output per watt are the characteristics of cold cathode as contrasted with hot cathode (29, 61-65).

While the popular hot cathode lamps are the 40 and 100 watt sizes, long slim lamps of the following sizes have been developed·

> 42T6 (42 in long, tube 6/8 in diameter), 64T6, 72T8 and 96T8 They are equipped with single pin base to provide maximum safety and convenience They are designed for instant start service on high voltage (450-700 volts) and can be operated at 100, 200 or 300 milliamperes for three steps of light output and brightness (61-62)
>
> A 40-watt hot cathode lamp has become available in a 60 in T-17 bulb to provide low brightness and reduce both direct and reflected glare (61)
>
> A new color for the 40-watt T12 and 100-watt T17 has become available and is rated as 4500K Its purpose is to serve as an intermediate step between the previously available 3500K and 6500K types The light output is approximately 5 per cent less than for the 3500K lamp
>
> One hundred and 300-watt filament blown glass reflector lamps are now available in *hard glass* for outdoor use where lamps are subject to thermal shock (62)
>
> A new 1000-watt quartz mercury vapor lamp has been developed as an extension of the 100-watt, 250-watt and 400-watt line of vapor lamps, particularly for use in high bay mounting (58)
>
> An 80-watt, 5 ft. length, 1½ in. diameter fluorescent lamp operating on 200-250 volt, 50 cycle AC circuit and developing 2800 lumens initially is the popular fluorescent lamp used in England (61)

Ballasts and Accessories

Aside from the currently used ballasts (66-67), new studies in ballasts for special applications and for determining the influence of ballast design upon the characteristics of fluorescent lamps indicate an enlarged sphere for the use of fluorescent lighting. It has been found, by elminating starter switches and arranging for continually heated cathodes, that the popular sizes of hot cathode lamps can be repetitively flashed with resultant long life (2500 hours) and nominal light output (68) High frequency operation of fluorescent lamps indicates a gain in efficiency, power factor and regulation with a resultant reduction in size and weight, for inductive, capacitive and resistance type ballasts Frequencies in the range of 300 to 600 cycles permit the use of very small, light-weight capacitive ballasts with maximum overall efficiency (69). Satisfactory operation of cold cathode fluorescent lamps has been established for 600-volt direct current systems even where frequent interruptions of the circuit occur in the field of transportation (70).

APPLICATIONS

Offices and Drafting Rooms

It has been found that a controlled environment with low brightness ratios can be accomplished through a combination of: (a) lighter room and furniture finishes, (b) well-shielded low brightness lighting fixtures, and (c) careful daylight control (6, 7). While recommendations are available in detail, a rough summary may be made as follows:

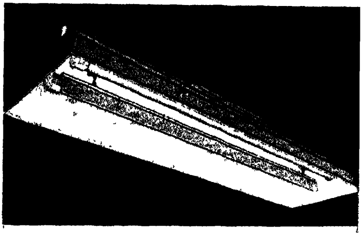
Room Surface Reflectances	
Ceilings	70 – 85 per cent
Walls	50 – 60 " "
Dado	30 – 35 " "
Shades or Venetian Blinds	40 – 60 " "
Furniture Reflectances	
Desks	30 – 40 " "
Equipment	20 – 35 " "
Lighting Fixtures	
(*Maximum brightness values*)	450 footlamberts horizontal to 45 deg below

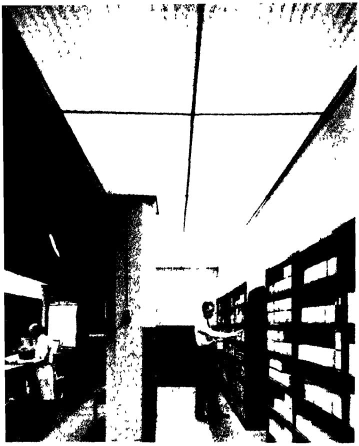
A recent analysis (10) indicates that the above recommendations produce ratios up to 7 to 1 for most systems of lighting but when the lower parts of the room have low reflectances the ratios rise to 30 to 1.

A variety of attractive well-shielded low brightness lighting fixtures are now available as evidence by the exhibits at the recent International Lighting Exposition (71) Care should be taken to check the shielding and brightness measurements in the zone from the horizontal to 45 deg below to see that they meet the recommendations as given above

Much interest has been directed toward so-called *louverall* ceilings in which the complete ceiling is louvered to hide at casual viewing angles the lighting equipment, structural non-uniformities and mechanical equipment (pipes, sprinklers, etc) Such ceiling elements are now production items and are available in several patterns, sizes, materials and finishes The approximately 6 in hexagonal type stamped from matte surface aluminum gives a honeycomb effect which permits slight misalignment without apparent distortion The cells can accommodate reflector spot lamps on adjustable mounting for highlighting A small 2″ x 2″ x 2″ vinylite plastic arrangement allows for both transmission through and reflection from the louvers producing a highly efficient, attractive pattern or texture The eggcrate type made of light gauge steel,

Center baffle in industrial fluorescent unit gives approximately double shielding angle against glare.





Louverall ceiling using vinylite plastic material in 2" x 2" x 2" openings.

Up-to-date photometric laboratory with 22 ft high ceiling. Black terrazzo floor is divided into 12 x 12 in. squares by zinc strips. Measurement guides for obtaining exact illumination data also permit an inclosed distance of 72 ft. Ceiling outlets have lowering devices for testing units at various mounting heights.

finished in white enamel has proven very satisfactory in many designs of louvered lighting fixtures during the last few years. Helpful design information is available (72)

Reflections of lighting fixtures (or lamps in the lighting fixtures) in dark polished desk tops or glass tops cause distracting annoyance or actual veiling reflections in glossy papers (books, tracing paper and cloth, etc) These are alleviated by continuous lines of light, diffusion of light downward, luminous indirect lighting (73) or orientation of lighting fixtures in reference to desks (74) A recent study analyzes the relationship of reflected glare to the office tasks (75)

PERCEPTION OF INDUSTRIAL TASKS

Opaque objects or materials have been classified into two dimensional flat surfaces and three dimensional objects with shape and contour Perception is influenced by the reflective characteristics of the surface involving the degree of gloss and color and the three dimensional spatial relationships as revealed by highlights and shadows (7, 76)

Two Dimensional Under Surface with Gloss

Directional light oriented to eliminate reflected images is used to reveal the color and texture of surfaces having a degree of gloss

Two Dimensional Non Glossy Surfaces

Reflected images of large, low brightness areas are used to reveal marks, scratches or defects in glossy surfaces Uneven coating or polishing is revealed by distorted images reflected from symmetrical lines on low brightness surfaces Reflection of large luminous areas are particularly appropriate for working on metal surfaces which have a considerable degree of specular or roughly polished, as well as highly polished, surfaces (77, 78)

Three Dimensional Non-Glossy and Glossy

Three dimensional opaque objects are seen both from their two dimensional surface characteristics as well as from their spatial relationship as revealed by highlights and shadow Light from a large diffusing area such as the sky or a brightly lighted ceiling produces completely diffuse and shadowless illumination because light comes from every direction to eliminate shadow Light from a concentrated directional source produces a high lighting of surfaces facing in its direction but casts shadows on surfaces turned away or hidden from its beam A happy combination of each is suitable for revealing the spatial contours of a three dimensional object—highlighting on important surfaces to be seen combined with softened shadows to reveal contour. Nature presents a good example with proportions of 4 parts of directional sunlight to 1 part of diffuse skylight at 22 deg. sun altitude and 10 parts to 1 at zenith in June. Highlight images of luminous surfaces or lines of light often help to reveal contour.

Slight Three Dimensional Effects

Sometimes the lighting must be designed to show up slight three dimensional characteristics. The inspection of flat materials for ripple or washboard effects is best seen under directional light sweeping obliquely across the surface casting slight shadows beyond each ridge or ripple (79)

Transmitted Light

Cracks and foreign material are seen in transparent and translucent materials by transmitted light from luminous area sources (7) Seeds, unevenness and lens effects in transparent materials are revealed by luminous areas with criss-cross contrasting lines Scratches and small bubbles in transparent objects are best seen by edge or oblique lighting (77)

METALWORKING INDUSTRY

Steel Mills

Recent thinking in the lighting of steel mills indicates graduated lighting according to the severity of the visual tasks (7, 80-82) More filament than mercury lighting is used in this industry Many of the mounting heights are above 30 ft in relatively long narrow buildings so that high bay lighting fixtures with their accurate control of light toward the working area are desirable Design techniques for mercury lighting have been discussed (83)

Foundries

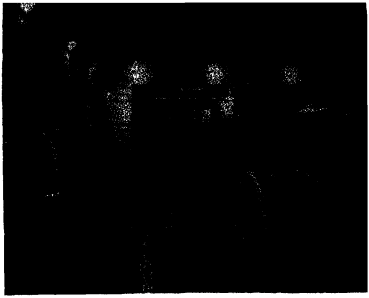
Recommendations for the lighting of foundries are made in accordance with the type of work carried on (7) and these are illustrated in descriptions of typical installations for general lighting (84) and inspection (85) An interesting artificial skylight effect was produced in a British foundry through banks of 6 80-watt fluorescent tubes in each fixture (61) The use of the 3000-watt tubular mercury lamp in a bronze and aluminum foundry decreased the number of units to maintain while producing 35 footcandles over 109,000 square feet of plant area (86)

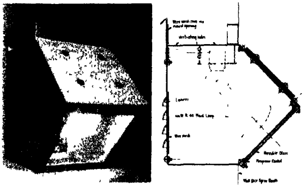
Forgings

The lighting of a grinding and polishing room for small forgings having an atmosphere of fine abrasive dust requires easily maintained industrial fixtures These should also incorporate a shielding of the lamps to produce a low-brightness, reflected image in polished parts (87).

Machine Shop

The operation of the machine shop involves work upon semi-polished or polished metal surfaces The machine tools may be roughly divided into horizontal spindle machines, vertical spindle machines, milling machines, shapers and planers The visual tasks involve the reading of semi-polished dials, gauges and machinists' instruments (micrometers and scales) and following the cutting tool Broad, low-brightness highlights are necessary for perception of the task. Current industrial lighting fixtures can be used to good advantage in a grid layout to produce highlights broader than from a single direction of orientation (88-93) Portable fixtures or flexible supplementary lighting are necessary for seeing into deep cuts or inspecting internal work. If the local lighting units are of sufficient candlepower the work surface may be seen by diffuse reflection from the grain of the surface (94-95) The tool and stockroom requires good lighting for rapid and accurate reading of the markings on tools and labels (102).

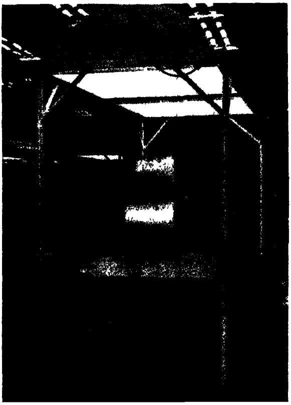




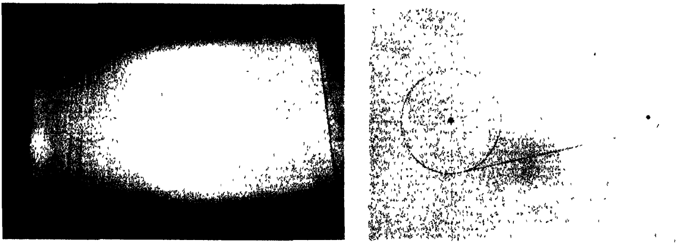
Lighting unit *Section through lighting unit*

GENERAL VIEW OF PAINT SPRAY BOOTH INTERIOR.

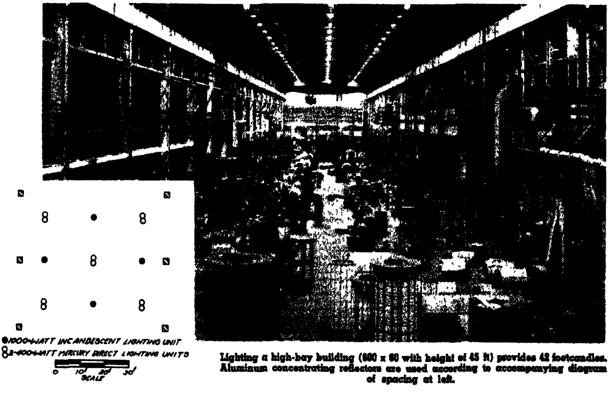
Portable lighting equipment for metalworking inspection reflects a large low-brightness luminous area on surfaces to be examined. Light passes through tracing cloth.



Poor and good lighting in a foundry. Visibility of work has been increased at right to reduce the safety hazard in handling molten metals. 18 in. reflectors were suspended 18 ft above floor on approximately 18 by 20 ft centers. Using 500 watt lamps an average illumination of 12 footcandles is provided.



At left scribed marks on semi-portable metal surfaces are masked by image of high brightness industrial reflector; at right the same markings show up in bold contrast when low brightness light source is reflected polished surface.



● 1000-WATT INCANDESCENT LIGHTING UNIT
8 2-400-WATT MERCURY DIRECT LIGHTING UNITS
0 10' 20' 30'
SCALE

Lighting a high-bay building (800 x 80 with height of 45 ft) provides 42 footcandles. Aluminum concentrating reflectors are used according to accompanying diagram of spacing at left.

Inspection of finished parts and accurate gauging is often carried on where special designs have been made to produce very broad highlights in flat and curved surfaces (96-99) Sometimes intermediate processes require colored lacquers involving special problems (100) or the inspection of parts require detection of very faint traces indicating the location of flaws or defects (101)

Sheet Metal Fabrication

The use of large, low-brightness highlights is involved in sheet metal fabrication The relationship of the lighting unit to the shear, the brake, the punch and the forming press has been recommended for optimum visibility of inscribed marks, scales and the raw material (103) Typical installations have been described for the lighting of a guide line on a steel shear (104), a power brake (105) and a punch press (106)

Welding

Welding involves the use of a hood with ultra-violet and infrared absorbing as well as light reduction glass lens A conflict between the eye adaptation under room illumination without the hood and the adaptation with the hood to a brightness of the welding arc of from 8 to 25 candles per sq in presents a problem However, installations of general illumination of from 30 to 150 footcandles have proved highly beneficial in assisting the transition and minimizing the eerie flashes Mercury lighting blends well with the color of the welding arc Fluorescent lighting is an aid to perception of metals due to its low-brightness images Lighting for various phases of welding and brazing has been recommended according to the conditions involved (107)

Assembly

Heavy assembly is generally carried on in areas where an overhead crane can move and assist in placement of parts This involves high bay type of construction in which high bay lighting equipment becomes appropriate including filament, concentrated mercury lamps, and 3000-watt mercury tubes Typical installations have been described using various arrangements (108, 109)

Line assembly is generally lighted from both sides with rows of closely spaced incandescent or mercury lighting, or more recently by continuous fluorescent industrial lighting, fixtures, sometimes tilted toward the assembly line if the work objects are high The objective is to produce a maximum penetration of light into all parts of the assembly with a minimum of shadow Since polished or semi-polished surfaces are involved in many cases, the larger, low-brightness images of fluorescent lighting are advantageous (111)

Bench assembly is lighted from closely spaced incandescent lighting over the worker's edge of the bench or from fluorescent lighting located lengthwise in front of the worker over the center of the bench, or perpendicular to the direction of the bench (112-113).

Finishing and Painting

Finishing and buffing require large, low-brightness highlights to detect roughness, burrs, uneven surfaces, etc Likewise the painting of lacquers is best accomplished under similar lighting to eliminate uneven application (58, 111, 114) Vapor-proof, fluorescent industrial fixtures above sealed glass windows to the spray area or explosion-proof fluorescent units in the finishing room give good quality illumination

Where glossy reflections are not a factor and matte finishes are used, concentrated incandescent light sources in suitably sealed housings or tight equipment with a maintained higher-than-room-air pressure have been used satisfactorily (115, 116)

Wire Manufacturing

Wire may be seen as it is drawn through the wire pulling machines by highlights which make it appear in contrast to its background The proper location of well-shielded, lighting equipment to reflect highlights to the eye of the worker is essential to good lighting (117)

TEXTILE INDUSTRY

The visual tasks in the textile mills involve primarily the perception of threads with little contrast between the individual thread and its background (118, 119) High values of illumination are necessary to perceive such fine details with poor contrast Recommendations for the lighting of each operation from the raw material to the finished product have been made (7) Due to the desire for elimination of shadow and for a comparative, white light source, fluorescent lighting has greatly improved the seeing conditions in the textile mills with many examples of good lighting for each step in the process of manufacture (25, 118 to 124)

Hosiery mills with difficult seeing tasks involving very fine thread have found 50 to 100 footcandles appropriate in recent installations (86, 126)

The garment industry also involves a number of important visual areas Inspection of cloth as it comes from the mill involves careful inspection for flaws and constancy of color The unrolling of the material generally occurs nears the windows to take advantage of the daylight The new fluorescent, daylighting lamps offer a good source to supplement the failing daylight or furnish a satisfactory substitute Sometimes color is not a factor and a large diffusing source furnishes a good inspection light For translucent cloth a large, low-brightness source behind the cloth is essential (127, 128).

The cutting tables are generally lighted by a continuous row of fluorescent industrial lighting fixtures mounted from 7 to 10 feet above the floor and over the center of the long table Recent trends in the lighting of the sewing machine tables indicate a possible changing over from small adjustable local lights at each machine to continuous rows of fluorescent lighting over the center of the tables, eliminating the high-brightness between the spot of light at the needlepoint and the rest of the table (129).

Needlework also involves fine detail with very poor contrast Localized general lighting of 100 footcandles with good diffusion is not too much for this type of close, exacting work

Cleaning and pressing work demands skill and close visual application in spotting and examining, in repair and alteration, machine finishing, in hand finishing and final inspection Recommendations in accordance with the task and its local conditions have been recently compiled (7)

PRINTING

Type composition and handling require that the characters be portrayed through the use of reflected images of large, low-brightness luminaires on the type surfaces (7, 130) The luminaire should have low (500 footlamberts), uniform brightness and be large enough for its image to cover the entire form The illumination level at the type should not be less than 50 footcandles

The same principle should be carried out for the presses Due to structural conditions some compromises may be necessary but nevertheless good lighting conditions can be effected (62, 131-132)

Inspection for quality control in color reproduction should be carried on in a booth or under conditions where carefully controlled lighting conditions can be obtained (7, 62, 133)

PETROLEUM AND PETROLEUM PRODUCTS

This industry presents a variety of conditions both indoors and outdoors which require illumination suited to the task from lighting equipment designed for hazardous or non-hazardous locations The lighting of the process equipment buildings, the instrument boards, the outdoor tower platforms, etc, has been recommended according to current practice (7)

MISCELLANEOUS

Abrasive Materials and Roofing Materials Light directed obliquely across abrasive paper or cloth or roofing materials reveals wrinkles and non-uniform coating (7, 79)

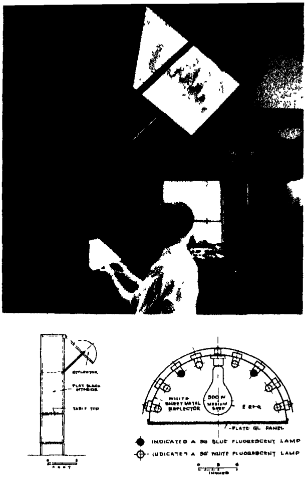
Presswood Board Imperfections in the coated surfaces are easily seen by the inspector viewing the reflection of a fluorescent luminous trough obliquely across the panels as they pass along the conveyor (134).

Enameled Steel A special booth has been designed to check the color matching of enameled surfaces which uses a hood equipped with blue and white fluorescent lamps (135).

Instrument Boards have been well-lighted from directional lighting units or a trough located above and in front of the boards at such a position as to eliminate masking reflections in the glass surfaces of the dials (7, 136 to 138).

Service and Repair Pits for heavy rolling stock have been lighted by tilted 4-tube fluorescent troughs covered with removable wire glass covers producing an average of 30 footcandles on the trucks (140)

Underwater Lighting for Detection of Leaks has worked satisfactorily with vapor-tight filament lamp lighting fixtures placed one at each corner of the tank about 2 feet below the surface to produce an average of 23 footcandles illumination in a tank, the inside of which has been painted white (141).


REFLECTOR
FLAT BLACK INTERIOR
TABLE TOP
FEET
WHITE SHEET METAL REFLECTOR
500 W MEDIUM BASE
-PLATE GL PANEL
INDICATED A 56 BLUE FLUORESCENT LAMP
INDICATED A 56 WHITE FLUORESCENT LAMP
0
3
6
INCHES

Lighting for color matching booth provides common color temperature to reduce variances. Cross-sections of booth and lighting unit are also shown.

Waterproofed Tarpaulins may be inspected and retouched by erecting a steel frame over which the tarpaulin is draped to form a tunnel in a lighted room having about 20 footcandles illumination The workers on the inside can detect breaks or poor coverage because of light transmission and then spray the areas involved (142).

Airplane Fuselages have been lighted in the interior by means of fluorescent industrial reflectors covered with wire guards located on the floor on opposite sides and tilted upwards (143).

Lumber mill operations are facilitated by a shadow line device by which the operator can set his saws to cut in certain widths Wires with lamp above them cast shadows at desired spacing (144).

Public Utility Generating Plant lighting has been described as a result of studies made of the application problems (29).

Illustrations for this chapter were obtained through the courtesy of the Illuminating Engineering Society, Benjamin Electric Manufacturing Co, Quebec Power Co, General Electric Co, Ferro Enamel Corp, General Electric Co.

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CHAPTER XIV

MATERIALS HANDLING

by SAMUEL W. GIBB

Every aspect of industrial activity from the collection of raw materials to the distribution of finished products involves materials handling The shipment of raw materials and goods within plants as well as over railways, highways, waterways and airways is a distribution and handling problem for which industry pays enormous sums of money each year Transportation facilities, therefore, have been forced to meet an increasingly competitive situation through more efficient and rapid handling services and equipment

Unfortunately, materials handling efficiency within industrial plants is only now drawing abreast of warehousing and shipping techniques Too often the cost of moving goods from storage warehouse to production lines, and out of the plants, has been hidden and disregarded by management Yet statistics show that 70 per cent of the average production cycle involves some phase of materials handling—pulling, lifting, carrying, placing, weighing, rehandling—representing 22 per cent of the total payroll

For more than a hundred years the most highly industrialized nations have been developing new machines and improving older ones in order to increase processing efficiency and improve the quality of manufactured goods Relatively, materials handling has remained in the handicraft stage The human body has continued to serve as the principal source for moving materials in and through a plant and for transporting the finished products to the loading platform

A significant forward step was achieved about the turn of the century when electric industrial trucks were introduced. But progress remained slow and only the more farsighted industries took advantage of this newly developed materials handling technique

A natural development of the electric industrial truck was the use of skids which permitted unit loads to be picked up and transported The further idea of elevating skids to fully utilize available headroom came later.

With the advantages of skids fully demonstrated in industrial practice, materials handling engineers recognized the possibility of utilizing unproductive headroom The fork or pallet truck was accordingly developed and has attained unprecedented popularity in the past few years.

The last war represented, in large measure, a war of supplies. Plants and storage warehouses bulged with goods awaiting distribution to centers of consumption. Speed was essential in moving these goods. The imporstance of modern materials handling methods was finally given full recognition (1).

Actually, not too many innovations in materials handling equipment were made during the war period. But new techniques, or at least techniques which had largely been neglected by industry, were fully exploited for the first time New and improved systems of overhead conveying were installed Materials, stacked upon platform or skid, were moved by *unit loads*, utilizing fork trucks to ship or store And, perhaps most important of all, goods moved vertically as well as horizontally (2) Instead of being stacked manually, goods were piled to girder heights, thus using every available inch of space in a plant or storage warehouse (3).

Unit Loads

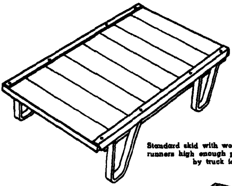
One significant advantage of this system of unit loads is that expensive packaging can be almost entirely eliminated It was extensively utilized by the Naval Ordnance Materials Handling Laboratory during the war, and with such success that many industries followed the pattern for peacetime distribution Unit loads can be most advantageously employed when a system of package standardization and simplification is adopted The General Electric Company, for example, found that even bulky insulators could be moved safely by this method Today an enormous range of products—from plate glass and acid carboys to delicate sub-assemblies and machine castings—are unitized on pallets for movement both within and between plants Where added protection is needed, however, a special package for the entire pallet load can be developed (4)

Recent experiments have been conducted to develop unit loads which will require no strapping, and so simplify materials handling within a plant One method, popular with cartoned and bagged goods, has been to glue units of the load at the top and bottom by means of an adhesive This adhesive must be strong in shear, yet pliable enough to permit ready separation by a sharp upward yank at one of the edges. Some have advocated that the load be glued, in turn, directly to the pallet, but the tendency is to glue it to a chipboard tacked to the pallet (5)

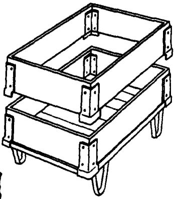
Lifting, Stacking and Tiering

The skid was originally developed only to help in picking up and transporting materials The idea of utilizing skids to stack came later In this initial stage of development, the only types of skid-handling equipment were hand lift trucks and power operated, low-lift platform trucks. The tiering and high-platform trucks were subsequent developments

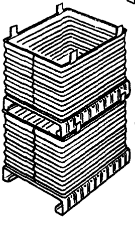
The skid is essentially a platform elevated about a foot off the floor (6). Pallets, however, are set lower,



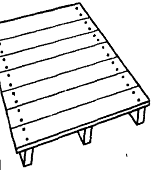
Standard skid with wood platform and runners high enough permits handling by truck forks



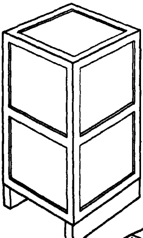
Addition of section frames converts skid platform into bin for handling loose parts.



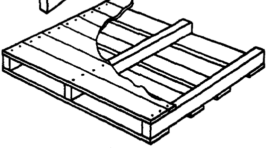
All-metal skid bins act as containers for heavy units. Retaining flanges make tiering safe



Wood pallet has a center runner for extra rigidity Entry is made from either end



Crates should have runners or stringers to speed handling in storage and shipment.



Solid-deck, double-face pallet has bottom boards spaced to permit lift by hand or electric fork truck.

so that less space is wasted in stacking and tiering. Another advantage attained through the use of pallets is that, except for the single-faced variety, little or no dunnage is required in stacking In addition to these space-saving features, pallets are much lighter than skids (7).

Double-faced pallets are the most common and come in three types, permitting entry of the forks from two sides, from four sides and from four sides plus the corners These latter are known as eight-way pallets and are most often employed when it is necessary to maneuver the fork truck in close quarters (8, 9)

Pallets are relatively easy to stack and store when not in use In fact, the same trucks used to stack loads can be employed to stack the pallets themselves Some attempt has been made to organize pallet distribution pools to eliminate the costly procedure of returning all pallets to the plant Thus, a number of manufacturers could share common pallets, loaded at all times, which would move from one plant to another. (10)

Any type of pallet handling pool would necessitate a greater amount of standardization in pallet design and sizes than now exists During the war an important step was taken by the United States Navy in reducing the sizes to two, 48 by 48 in and 35 by 45½ in The larger size was particularly suited to rail transportation since two could be placed side by side, almost filling the width of a freight car (11, 12) However, it is doubtful whether commercial users of pallets can reduce the number of sizes to two (13)

Reduction in the cost of pallet returns might be approached from another angle One manufacturer has produced a double-faced, 48 by 48 in paper pallet which is said to be priced low enough to be discarded at its destination. This paper pallet, incidentally, will support 3,500 lbs in shipment and 10,000 lbs in storage Another type of pallet, of impregnated fiberboard, will support a 5,000 lb load of brick on a surface of 8 sq ft (14, 15, 16).

Trucks More Versatile

The use of pallets is directly associated with the widespread use of materials handling trucks Principal developments in recent years have aimed at making trucks more versatile as well as more efficient. This has been achieved by designing trucks which will use every available inch of "air rights" by stacking pallets and skids to girder heights (17).

After the advantages of skids and pallets had been demonstrated to industry, the next logical step was to eliminate all unproductive headroom The result was the fork or pallet truck which has made such rapid strides in recent years Today forks raise to 268 in., as high as any heights previously attained, while permitting collapsed heights down to 83 in needed for a truck to pass through the average factory door or freight car (18).

It should not be assumed that fork and pallet trucks have or will completely replace the platform truck, despite their greater versatility. Fork trucks have a shorter turning radius for a given wheel base, can stack higher and can come closer to a load than a platform truck (19). On the other hand, the fork truck has certain disadvantages. It has no outboard wheels under the load, unlike the platform truck, to give stability. This means that it must be counterbalanced, making it heavier and more expensive than platform trucks which will handle a similar load As a result, the fork truck will weigh, on the average, only half as much (20, 21).

But within these limitations, fork trucks have found an established function in materials handling New applications and improved performance characteristics have followed industrial needs New models have been built with a lower mast in order to function inside a truck or semi-trailer Both fork and platform trucks are available in telescopic and non-telescopic models (22)

But within these limitations, fork trucks have found an established function in materials handling New applications and improved performance characteristics have followed industrial needs New models have been built with a lower mast in order to function inside a truck or semi-trailer Both fork and platform trucks are available in telescopic and non-telescopic models (22)

The fork truck generally enjoys certain advantages in maneuverability One is improved riding ability of the load Another is that fork trucks can commonly be tipped forward five degrees and backward up to 20 degrees The latter is extremely important for maneuvering in close quarters (23)

Truck Attachments

In addition to the standard models of electric industrial trucks, manufacturers are developing numerous attachments which either replace or complement regular forks or platforms These can usually be installed on trucks of any design or size, and are built expressly for a particular job (24)

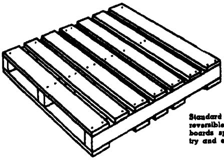
A widely employed special truck attachment is the ram, which finds numerous applications in moving coiled stock in the metals industry Another attachment has forks with projections for handling this material. The pulp and paper industry widely employs a paper roll truck with a special rotatable scoop which can pick up a roll of paper from either the horizontal or vertical position (25, 26)

A number of devices for handling tin plate have found acceptance in the metal working industry Rotating attachments for dumping bins after lifting them are common Hoops to let down over barrel and drum tops are frequent. Fork extensions prove useful in many cases Booms sometimes replace the forks for handling engines, and the like, which must be suspended

Still other fork attachments enable a truck to handle unpalletized goods One such attachment automatically pulls an unpalletized load onto the forks and later pushes it off the forks (27) In conjunction with this attachment, a corrugated metal structure may be used to enable the truck operator to pick up a load whether it is palletized or not Simple wooden stringers are often placed to provide clearance under non-palletized loads Such devices, together with clamp attachments, are particularly valuable for handling unpalletized loads in plants which customarily handle pallets

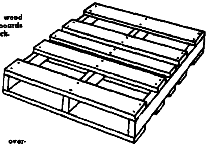
A novel device has been developed in handling bricks. No pallets are needed here because projections on the special fork tines grip the bottom row of bricks, automatically engaging them as the fork is lifted into the carrying position (28).

Light materials can often be dug and transported

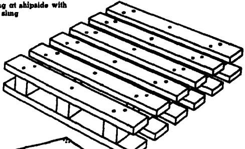


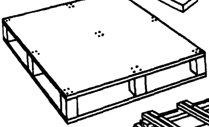
Standard double-face, non-reversible pallet with bottom boards spaced to permit entry and elevation by hand or fork truck.

Reversible double-face wood pallet with lower deck boards to permit lift by truck.

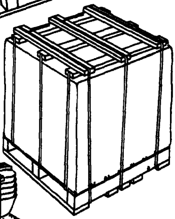


Stevedore pallet has overhanging deck boards to facilitate handling at shipside with sling

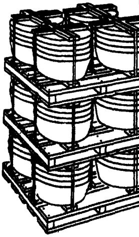




Reversible 4-way-entry pallet is extremely versatile Entry and lift possible from any side



The paper industry was first to steel-strap shipments to skids and pallets. Tin plate is now handled this way; other industries can profitably utilize this method.



Nested products may be strapped on pallets and handled as a unit, saving time, packaging materials and space with a special scoop which fits under the forks Such an attachment is commonly used to dig, carry, elevate and dump bulk fertilizer, ashes, coal, raw materials, scrap, etc (29)

Countless numbers of these versatile attachments are available for either fork or platform trucks Some of them can be added to the truck without change, others come as specialized accessories to fit the truck, many are built by inventive users for their own purposes only, while still other attachments necessitate a modification in the truck But in all cases they make fork and platform trucks capable of more versatile operation than intended by their original design (30)

The "Walkie" Emerges

Within the last four years a new type of powered materials handling tool has emerged It is guided by hand, like a hand truck, but its propulsion, lifting and load-manipulating functions are all electrically powered like the full-scale ridden shop truck The operator controls from the guiding handle It brings the benefits of fork and platform truck handling into a wider range of industrial application It is lighter, cheaper, suitable for shorter hauls and closer manipulaiton and anyone in a plant can operate it at any time Yet muscle-power is eliminated to such an extent that women operators are common.

At least four major manufacturers now make this equipment One company has developed a complete line of seven different types (a) low-lift platform, (b) low-lift pallet; (c) tinplate unit, (d) high-lift platform, (e) tilting fork, (f) non-tilting fork, (g) tractor Another company makes a pusher" model

Such units, variously called "walkies", "worksavers" and "transporters", promise to carry *full mechanization* of effort down to the humblest shop and smallest budget They undoubtedly represent the greatest single development in materials handling equipment since the war (30, 31)

Combination Handling

To what distances is it economically feasible to move pallets and skids on fork and platform trucks? It is generally agreed that platform and skid trucks are economically advantageous only in moving goods a relatively short distance When there is a substantial distance from plant or warehouse to truck, car or ship the intermediate use of tractors and trailers becomes justified Sometimes goods are moved from plant to storage by means of a trailer, but are unloaded by a fork truck for tiering

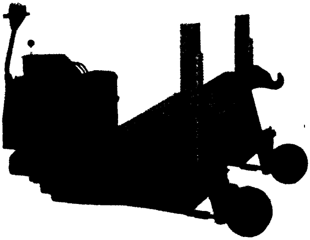
Lately a great many trucks have appeared which are combinations of different types of equipment, so that two or three basically distinct functions may be performed by one truck Platform trucks have been fitted with cranes and couplings so that they can hoist, slue boom and tow Cable and winch attachments on both high-lift and fork trucks have permitted the addition of horizontal pulls to vertical lifts Dump hoppers and dial scale systems have been built integrally onto simple load-carriers for use in batching work

Loading pallets into automobile trucks presents special problems If a loading dock is available, a hand or "walkie" truck may be employed If not, it is advisable to use a fork truck When the truck sides are not removable, the fork truck can feed the goods from the back either by shoving each ahead with the last (if truck traction is sufficient) or by means of rollers placed on the truck bed (32)

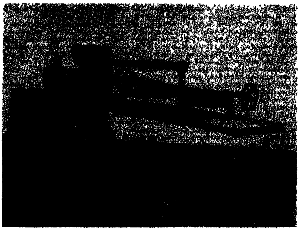
Hoists and Scales

Although hoists and scales are familiar materials handling tools, there is increasing activity in their development and enormously wider usage Perhaps the most significant trends in hoists are (a) toward wire-rope-and-drum type lifting, and (b) the development of many ingenious grabs, tongs, grips, slings and other attachments for accommodating wider varieties of work with greater safety In dial scales, much has been accomplished in integrating weighing equipment with materials handling systems--monorail or roller conveyor sections, batching machinery, truck systems, etc The counting scale is becoming very important in continuous inventory control The crane scale, which weighs while the lift is being made and thereby saves two rehandlings, has been found increasingly useful (33).

3 ton motorized hand truck for handling coiled materials. Hooks are adjustable for various diameters.



Steel plate handler handles 3000 lb load with forward and backward tilt. Uprights stack sheet 10 ft high.



Conveyors

Much materials handling within a plant is accomplished by means of a conveyor system No hard and fast rule can be given to guide the industrial engineer in selecting either a particular type of conveyor or in selecting a conveyor over other means of moving goods All decisions must be based upon a consideration of the limitations as well as the advantages of the various materials handling systems and an analysis of the materials to be handled Frequently, the most satisfactory materials handling layout will include a judicious combination of pallets and electric trucks, conveyors and elevators

Where a large volume of materials flows through a plant in a defined line, an adequate conveyor system often proves to be a cheap and efficient method of moving goods

Materials handling engineers predict a wider utilization of conveyors and chutes throughout industry to eliminate or ameliorate wasteful manual handling on a production line One excellent example of the intelligent application of conveyor systems was provided this past year by a textile mill and without any great outlay for new equipment Here the number of "pick ups" of cones during winding, inspection and shipping were reduced from five to one, at a saving of $220 20 per 100,000 cones The improved method enabled an operator to inspect, wrap and pack the cones on a special hand truck complete with table, picking the cones from a moving conveyor belt (34)

Another instance of the intelligent use of conveyor and auxiliary equipment was recently demonstrated in a metals fabrication plant in Illinois Here bulky metal cabinets were fabricated and finished in three operations 1 Forming of the outer shell 2 Fabrication of the doors and miscellaneous parts, 3 Painting, baking and final assembly of the complete unit Power and free conveyors were used, including roller, slat and overhead types A color system was devised to differentiate parts utilizing the same overhead conveyor system The net result was reduced floor space, improved quality and lower costs (35)

It should be pointed out that about 80 per cent of all conveyors are especially designed and built to individual specifications This means that no one type will fit all conditions and every plant Each type, or combination has its particular application Its efficient use depends upon plant facilities, layout and the bulk, weight and durability of the product handled

Gravity Conveyors

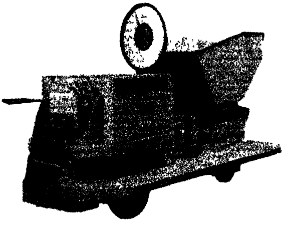
As the name implies, these conveyors utilize gravity as motive power for moving goods about a plant or along a production line One popular type, the gravity roller conveyor uses rollers moving on fixed bearings The space between rollers depends upon the product being moved Moving empty drums through a petroleum refining plant provides an excellent example of its specific industrial application These conveyors come in short sections, are especially desirable for making a differential curve, and can be mounted on portable stands where mobility is desired (36 37)

The roller spiral conveyor has been extensively employed in moving materials from one elevation to another on a floor or between floors It is sometimes selected in preference to a chute because materials can be moved with relatively little jarring It has been extensively adapted in handling fragile products such as glassware and preserves packed in jars Moreover, the load can be backed up without clogging so that the conveyor itself may be used as a storage run (38, 39)

Recently a manufacturer introduced a 3-way switch for roller or wheel conveyors This switch, controlled by levers from a single point, will pick up a part or package and move it in any of three directions No manual guidance is required

Packaged or bulk materials are often conveyed on aprons or belts for continuous movement of materials through a plant The apron conveyor, made up of wooden or steel slats, is particularly suited to handling bulky miscellaneous packages Materials can be moved either horizontally or on an angle as great as 45 degrees, with cleats, blocks or brackets to keep the materials from shifting when the angle of incline is severe (40, 41)

Weighing equipment is integrated with truck to facilitate accurate measurement and disposal of materials.



Special head for fork truck can pick up and revolve rolls of strip steel through 90° and stack them in any position.

Belt conveyors utilize a variety of material, including woven cloth, flexible steel, leather, wire mesh, or cloth covered with rubber and various impregnating materials (42) This form of conveyor has found its widest application on assembly lines and for handling packaged merchandise (43). However, trough belt conveyors are suited to bulk materials such as sand, coal and grain (44).

Motive Power

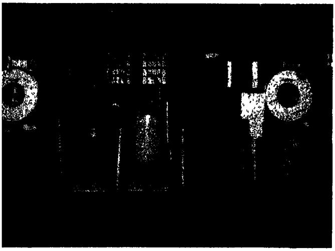
While motor-power belt conveyors handling packaged goods usually move about 100 feet per minute, speeds as high as 200 feet or more have been successfully used (45) During the war, canvas belts were extensively used because of shortages in rubber, but materials have a tendency to slide back unless the canvas is covered with rubber or other material Rough-surface rubber belts will move packaged materials on angles as high as 27 degrees, and even greater inclines are feasible through the use of cleats and arms (46)

An authoritative survey has shown that moving materials on shipboard by means of conveyors is far more efficient than the use of ship's booms and winches (47)

Belt conveyors in recent years have been designed for increased portability Some are mounted on wheels or casters, with take-up and drives pulleys similar to stationary models. Two large wheels are usually centered beneath the conveyor for movement from place to place and to serve as a supporting element when the feed end is lifted off the ground These are most often used for loading and unloading cars, trucks, trailers, barges and other transport vehicles (48).

Increased belt conveyor mobility was recently achieved by a company in Ohio which had warehouses in different parts of the same city In order to utilize one conveyor for its scattered locations in loading and unloading raw materials, a 24-ft continuous conveyor belt was mounted on a tractor Provided with a hydraulic lift mechanism, the conveyor front can be lifted 24 feet off the ground, which is sufficient to load and unload into the second story of a warehouse Actual construction of the tractor conveyor was simple Four uprights and four diagonal brace rods were used to mount the conveyor on the hydraulic lift, and welded in place (49).

When materials moving along a belt must be distributed at various points or deposited in bins and



Roller platform is integrated with conveyor system to get oil gallonage by weight.

Specially designed grab bars hook under ends of pallet and lift load from tractor-trailer into hold of ship.

Tiering of crates utilizes floor space to the roof.

Single-stroke hand lift truck performs multiple jobs.

hoppers over a long storage area, a tripper may be used. This tripper is used principally for bulk materials, while a deflector or tripper arm suffices for packaged goods These two principles were recently modified in a machine parts plant where a dividing device on the belt brings parts to each operator on a smaller belt (50).

Screw Conveyors Have Specialized Use

A continuous or broken-blade screw or ribbon fitted into a suitable trough, with the revolving screw moving the material forward, has certain specialized uses in industry (51) For example, materials in bulk, such as meals, seeds, cereal and sawdust, are economically moved by this means However, there are certain limitations in its use, since bulky materials or those contaminated by contact with the screw cannot be handled In addition, sticky material will probably stick in the trough or around the screw (52) Materials moved through a screw conveyor can be delivered through a bottom opening or at any intermediate point, the discharge being controlled by gates

An American manufacturer has developed a new type of twin screw conveyor with a welded spiral of steel built around each of two pieces of steel tubing. The tubing revolves by means of an electric motor This twin screw conveyor has proved useful in unloading bagged materials from railway cars The conveyor is built in small sections, with gravity chutes to move the bags from one section to another (53)

Combination truck-trailer and hoist finds innumerable uses in yard and buildings with savings in man-hours.

Tilting ram truck built for heavy duty in rolling mills moves finished products and saves on production costs.

Overhead Systems Save Space

The overhead conveyor system has attained popularity for a number of reasons, but the principal one is that it conserves valuable floor space in a plant or warehouse In addition, it is well adapted to unloading operations at work heights, can move above production machinery, and provides excellent means of transporting materials between adjoining buildings (54)

In a continuous overhead conveyor system, such as monorail chain, the trolley runs along the rail or track Materials are carried by the trolley by means of hooks or other means, and the line of travel is continuous since the rail can be made in a 180 degree turn

Recently a firm handling railway express successfully applied the overhead conveyor system for hauling trailers, instead of using the tractors as previously An overhead chain 2,100 feet long was installed to unload packages from freight cars and to transport them to trucks for delivery In this installation, caster-type trailer trucks are moved 80 feet per minute Grocery warehouses have also employed this trailer and conveyor set-up (55)

In one plant, coils of cable are tested while being moved along an overhead conveyor The cable is carried through an immersion tank as an electric current is applied for testing purposes Interchangeable carriers are employed to handle different items, and variable spacing is provided on the conveyor chain.

Manufacturing Costs Plus

One overhead conveyor system has been designed to serve as a "traveling stockroom" Orders are moved to the shipping department along the conveyor so that aisles are not clogged with trucks In another plant, parts are brought to the assembly table by the conveyor at a great saving over previous methods (56).

Production costs in any plant, if they could be logically broken down and evaluated, would divide themselves into fabrication or processing costs *plus* the cost of materials handling Unfortunately, the latter costs are often hidden and even the most refined system of cost accounting will find that most elements of materials handling costs are buried with items which relate to manufacturing.

The first step toward locating and evaluating these hidden costs must be a thorough study of the flow of materials within a plant. One method is to draw a floor plan of the plant, to scale, with symbols employed to indicate doorways, ramps, elevators, bridges, outdoor movement, etc Often such a diagram will suggest a better plant layout, resulting in the relocation of machine tools, storage zones and receiving points (57).

Inefficient movement of materials and superfluous handling will become apparent. For example, in one plant it was discovered that forgings were handled 21 times, using five different types of materials handling equipment. Twenty-two men were required to move the forgings almost a mile, wasting an hour and a half in transportation time This simple survey indicated immediately a need for a more logical movement of materials through the plant

Since it would be uneconomical to survey all materials moving through a plant, a few representative parts will usually prove sufficient to obtain an over-all picture Selecting a hypothetical case, a manufacturer of textile machinery might produce 40 machines per day, each with 900 parts By tracing the movement of a sample part or lot, it is possible to estimate the total cost of handling all units

A thorough materials handling survey will prove an accurate guide for a revision of plant layout, the use of more efficient loading methods, and the installation of new materials handling equipment (58).

Intelligent management today recognizes that it is inefficient and wasteful to wait until bottlenecks develop in the movement of materials In the same measure, haphazard cost cutting will not get to the root of the problem Rather the *total* materials handling picture must be surveyed if cost is to be reduced and output increased

Illustrations for this chapter were obtained through the courtesy of Automatic Transportation Co, Elwell-Parker Electric Co, Baker-Raulang Co, and Yale & Towne Manufacturing Co

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CHAPTER XV

METALLURGY

by FRANCES HURD CLARK

Physical metallurgy covers the properties of metals encountered in their fabrication and use, and the laboratory methods of testing developed to accomplish these dual aims. This review has tried to emphasize the contributions to physical metallurgy since the war and to point out some of the changes brought about by the war where this information has only recently been released.

In a report of this brevity, details are necessarily lacking, but it is hoped that the bibliography as outlined will lead the interested reader to examine the original papers. Since the stream of fundamental research work in physical metallurgy that in former years stemmed from Germany (180) has ceased to exist, the sources of this review have come principally from England, Switzerland, and the United States.

FERROUS METALLURGY

Iron and Steel

Since the close of the war, a record peacetime production of steel has been established with a prediction for 1947 of 85 million tons or 93 per cent of the total steel production of the United States. Even at the end of this year, shortages still exist in many classifications. No review of post-war developments can be complete without mentioning the tremendous implications aroused by the use of oxygen to speed up melting and refining operations both in the blast furnace and open hearth. From modest attempts on the part of producers of oxygen to increase consumption of this gas by the steel industry, the response has been so great that, due to limited oxygen supply, available quantities are now rationed (2, 3).

The use of oxygen in the open hearth speeds the refining period so that heats may be reduced from 13 to 5 or 6 hours. This question of the time element appears to be the most attractive feature of the process which must be balanced against the cost of the oxygen, the life of the refractory, especially that of the roof of the open hearth, and the change in raw materials charged into the furnace (4).

Several methods of introduction of the gas have been developed: (a) A high pressure jet of oxygen is directed against the pre-heated scrap to speed the melt down to clear a path through the scrap to the end burners. (b) During the removal of carbon in the refining period, a stream of high pressure oxygen is introduced by an ordinary pipe under the surface of the metal. This is known as the lance method. (c) During the removal of carbon in the refining period, a jet of high pressure oxygen passes through a specially designed nozzle to a point 3 to 6 in. above the surface of the slag. The high velocity of the jet blows away the slag allowing the oxygen to react with the steel bath. This is known as the jet method. The use of oxygen during the refining period increases the rate of carbon elimination and results in the saving of fuel from the added heat. Other experiments have been devised adapting the lance method to the use of compressed air, which has effects similar to oxygen in removing carbon from the bath. The introduction of pure nitrogen to increase the reaction rate has proved interesting in decreasing the time of the heat, but no saving of fuel resulted as the inert gas has a cooling effect.

The problems involved include agitation, intermixing of slag with the steel, the furnace atmosphere, and the heat units that can be counted on so that the cooling effect of any gas used may not be too great. The refractory problem itself appears to many experimenters to be the most critical as splashing of hot metal on the open hearth roof has been disastrous. Even with increased height of the roof, the fumes of iron oxide corrode the roof severely. Excessive fumes carried to the outside atmosphere must also be eliminated. However, the cost of oxygen will probably be the determining factor. Many predictions are now forthcoming to indicate that large scale production may reduce prices to less than $5.00 (U. S. cy) per ton. The effect of oxygen on the steel itself up to the present time seems to be negligible with the exception that rimming steels may have somewhat less gas (5 to 10).

Hardenability of Steels

The addition of boron to steel control hardenability is still of considerable interest (11, 12) as evidenced by a study of a series of open hearth heats varying from 15 to 180 tons containing different amounts of boron. Conditions of adding boron to the ladle after other additions and to the ingot during teeming were observed. The hardenability factor for boron was determined from end quench tests. The effect of carbon content on the hardenability of boron steels has been determined.

The use by the consumer of hardenability bands for the selection of steels is increasing steadily due to the help given in fabricating and heat treating problems which in the past have been difficult to define in a concise way (13). Hardenability bands for the "H" steels were first published in June, 1944, and have since found wide application. Many steels have been added to the original list (14 to 17) so that today the user should get better control of hardness which formerly varied from lot to lot. In the manufacture of steels which must fall within limits set by the hardenability band, such factors as grain size control, oxidation method, and alloy balance must be included. In England, control of hardenability in steel is largely accomplished by additions of aluminum and titanium.

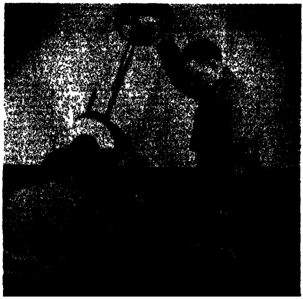
The use of the Jominy test and the end quench test are still accepted methods for determining hardenability. The Jominy test provides the maximum hardness and maximum strength at about 600 deg F per second which is the fastest possible cooling rate in a commercial shop. It also gives the depth of hardness, the mass effect, the probable microstructure of the steel, and the mechanical properties

Properties of Steel

In former years, sulphur was added to steel to improve machining characteristics. In stainless steel where nickel and sulphur form an undesirable compound, the stainless steel becomes hot, short, or brittle and is difficult to roll due to hardness It will also have a poor surface. Selenium is now available as an addition with improved machining qualities imparted to the stainless steel. Selenium also improves the rolling and adds structural toughness This alloy has found wide use in dental, surgical, and food handling equipment (46).

The question of the passivity of stainless steel has been raised again and it is claimed that the common practice of using dilute nitric acid does not result in passivation (47) The usual dilute nitric acid treatment may remove imbedded iron particles from the rolling operation but this is its only advantage according to the report above It is claimed that passivation is due to physically adsorbed gas attached by Van der Waal's forces and represents poor adherence or weak bonding of the layer to the steel Tests show that passivity is broken down under vacuum and is built up on exposure to air. The best method for passivation is immersion of the stainless steel in boiling sulphuric acid for 3 minutes In general it may be said that pickling after a forming operation is entirely sufficient as an effective means of passivation.

Steel sample at a very low temperature being tested for impact strength. Temperatures as low as —300 deg. F. are used.



An attempt has been made to evolve a mechanical equation of state in certain steels (22) where the condition is so fixed that there is no strain aging, no recrystallization, no graphitization, no phase change, and no corrosion taking place Under these special conditions, an equation may be set up involving a mechanical equation of state to show the effects of tempering Tension tests of the true stress strain type conducted on a steel of S A E 1045 indicate the effects of tempering on the true strain properties

Since the stress reaction in a material governed by a mechanical equation of state is fixed by values of the instantaneous strain, the strain rate, and temperature, then the previous history of the steel is important. Where this equation holds, a specimen may be extended rapidly to a given strain at room temperature, then stressed at elevated temperature and the creep measured This would be the same rate for the same strain measured over a long period as for months or for years By the use of the mechanical equation of state, the strain rate versus the strain relationship might be found rapidly.

For the designing engineer and metallurgist, great interest will be aroused by a new book (23) on ferrous metallurgical design It has been written to give the designer methods for using the information published on the problems connected with selection and heat treating of a steel part The first chapters are devoted to the most recent advances regarding phase transformations, heat flow, and mechanical behavior and properties Next follows the newest evidence on quenching, hardenability, quench cracking, and temperability

The remaining section of the book outlines a practical procedure for the designer which is unusual but should be considered by everyone selecting a steel for a particular part where the hazards of manufacturing, such as machining, heat treating, and service life play important roles. The procedure can be outlined as follows

(a) Determine the general features of the quenching method and the dimensions of the section of the particular part which will cool most slowly

(b) Estimate the hardenability required to harden this section with the quenching procedure chosen.

(c) Select the carbon level and the type of steel to be used Estimate the level of alloying elements needed for the necessary hardenability.

(d) Estimate the austenitizing procedure and the tempering procedure.

(e) After several parts are manufactured they should be checked for hardening, quench cracking, and temper brittleness.

The method of selecting a steel for a specific part as suggested above is quite radical but the principles should be understood by all designers and its practice should be attempted. As experience is gained from the application of the hardenability concept, shop problems of heat treating failures and difficulties of wear and breakage in service should decrease

The same authors, Holloman and Jaffe, have published a study (30) correlating the microstructure and mechanical properties of two steels S.A E 3135 and N.E 8735 to determine if steels with different compositions have fairly similar properties if their microstructures are similar The S A E 3135 was selected because it could be made temper brittle while the N E. 8735 presented an interesting contrast in that severe temper brittleness could not be induced. The N.E 8735 was also chosen because in isothermal treatments it could be quenched to martensite in ⅝ in rounds and also because it had sufficient pearlitic hardenability to permit complex isothermal treatments. The experimental work consisted in producing a wide variety of microstructures in the two steels and comparing the resulting physical properties on the basis of their similar structures. The optimum mechanical properties for both steels were obtained with a tempered martensitic microstructure. It was also found that impact properties of the steels having a tempered bainitic structure are intermediate between a tempered pearlitic and a tempered martensitic steel of like hardness The presence of pearlite (plus bainite) in quenched structures of tempered specimens is reflected in lower reductions of area in the standard tensile test Although it has been known for some time that the rate of strain hardening is strongly related to the tensile strength and the carbon content, tests carried out in this investigation indicated that differences in structure do not significantly change the rate of strain hardening

During World War I much attention was devoted to the question of temper brittleness in steels (54) and the conditions suitable for its occurrence. Through the intervening years, interest in the subject waned although failures due to this phenomenon were not unknown Perhaps World War II was sufficient reason to rally interest in this problem but it is now generally agreed that practically all medium and all high alloy steels are susceptible to a loss of impact energy if tempered in a certain range of temperature or cooled slowly through that range. Another way of stating this problem is that temper brittleness lowers impact properties because it raises the temperature of transition from a ductile to a brittle failure.

Many failures are now attributed to the transformation which forms the underlying mechanism of this process. A recent explanation (52) of temper brittleness claims that a precipitate forms in a temperature range slightly below 1110 deg. F., that it is precipitated from alpha iron, and that it forms at grain boundaries. Impact properties are lowered by its presence but tensile strengths at room temperature are not altered. The elements manganese, chromium and nickel tend to increase the total amount of the phase which can precipitate and the amount which precipitates in a fixed time in the embrittled range.

A new metallographic etchant has been reported (34) which discloses the effect of temper brittleness at grain boundaries for a number of different steels. The responsible agent is a mixture of alkyl-dimethyl-benzyl-ammonium chlorides known as Zephiran chloride and is prepared as follows.

Picric Acid	50 grams
Purified Ethyl Ether	250 milliliters
Zephiran Chloride	10 "
Water	240 "

The mechanisms connected with the tempering of tool steels have been exhaustively studied by Cohen and are summarized in two reports (35, 36) which comprise informed opinion today The characteristics of the formation of martensite are generally agreed to be as follows

(a) It forms on cooling, and the rate of cooling is of minor importance

(b) Locked up stresses due to volume changes invariably accompany this transformation

(c) The presence of retained austenite is a feature.

Many metallurgists fail to appreciate to what extent the retention of austenite can be counted on With the usual quenching methods, retained austenite in plain carbon steels amounts to 3 to 12 per cent In low alloy steels such as manganese oil hardening, chromium ball bearing steel, and tungsten non-deforming steels, the figures are the same In 18-4-1 high speed steel, about 20 per cent austenite remains at room temperature. In the class of the higher alloy steels such as the air hardening high-carbon high-chrome (12 chromium, 1.5 carbon) and the alloy steel (5 chromium, 1 carbon), austenite is retained at 30 to 35 per cent

The bad features of retained autenite can be summed up as follows·

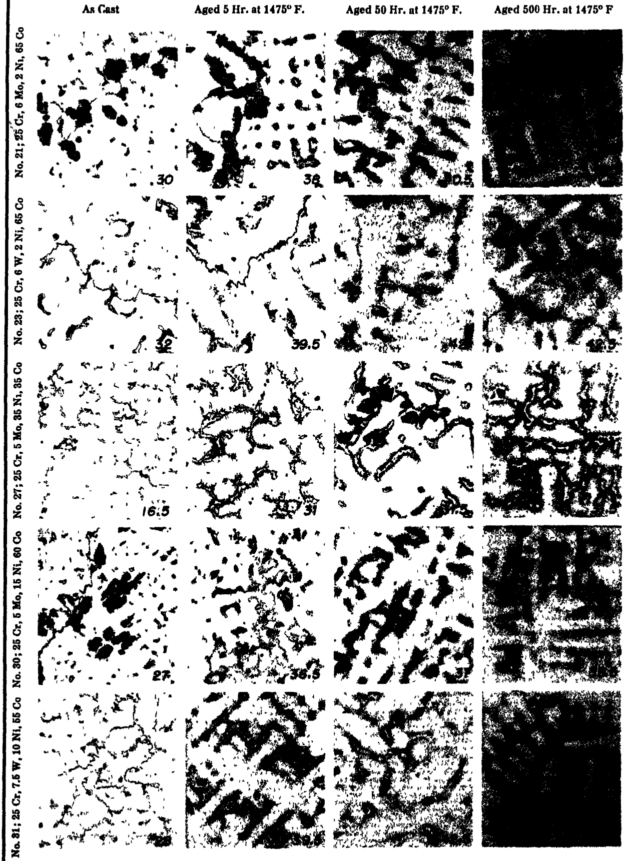
(a) That austenite is unstable cannot be emphasized too strongly This instability permits transformation under strains imposed by service and may well embrittle hardened steel.

(b) Some grinding checks are caused by volume changes resulting from localized austenite transformation under the pressure of the grinding wheel.

Micro-hardness tester and microscope measure single grain of steel at three points within the breadth of a human hair.

As-Cast and Aged Structures of Cr-Co Alloys

(Haynes Stellites; Magnification 200 ×; Rockwell C-Scale Hardness)


As Cast
Aged 5 Hr. at 1475° F.
Aged 50 Hr. at 1475° F.
Aged 500 Hr. at 1475° F
No. 21; 25 Cr, 6 Mo, 2 Ni, 65 Co
30
38
30.5
No. 23; 25 Cr, 6 W, 2 Ni, 65 Co
32
39.5
42.5
No. 27; 25 Cr, 5 Mo, 35 Ni, 35 Co
16.5
31
No. 30; 25 Cr, 5 Mo, 15 Ni, 60 Co
27
38.5
37
No. 31; 25 Cr, 7.5 W, 10 Ni, 55 Co

(c) There is evidence that retained austenite transforms slightly on aging at room temperature even without external stimulation. This causes dimensional instability and if the volume changes as much as 0.75 per cent this is 0.0001 in per in which is too great a change for precision parts.

The problem is then to form martensite under conditions which first of all will not result in any lowering of the hardness and which will subsequently perform the following changes (a) Toughen and stabilize the austenite, (b) Relieve internal stresses, and (c) Remove or stabilize the retained austenite

In plain carbon steels, the martensitic transformation takes place at 400-600 deg F, but in highly alloyed steels, it resists transformation due to sluggishness but can be conditioned in the 900-1100 deg F range so that it will transform to martensite on cooling from this range Double tempering of high speed steel relieves stresses and toughens the martensite formed during cooling from the first draw In general it can be said that, in passing from a plain carbon and low alloy tool steel to a high speed steel, transformation of retained austenite changes radically from an isothermal process at 400-600 deg F to a martensitic type of reaction on cooling from 1000 deg F In highly alloyed steel the austenite becomes so sluggish that it will resist transformation in the lower temperature range and hence can be exposed to a carbide precipitating process of conditioning at higher temperatures A study of the high carbon high chrome steels provides a connecting link for an understanding of the question

Heat Treatment

From tests carried out on S A E 52100 steels, it is evident that the higher carbon, low-alloy steels can be martempered to great advantage but good equipment is essential and overheating is especially to be avoided Martempering of S A E 52100 steel decreases distortion as shown by measurements on out-of-rounds of quenched bars (40, 41).

High Temperature Alloys

Materials to withstand the high temperatures required for gas-turbine operation represent a field of research that has become extremely active since the war. The range of interest can be divided into applications for airplanes where the life expectancy is a few hundred hours and applications for stationary gas turbines which must operate 10,000 hours, or roughly 10 to 12 years In England the first vessel propelled at sea by a gas turbine was launched in September, 1947 (72). It is equipped with two Packard 1250 hp gasoline engines designed for low cruising speeds and the new Metropolitan Vickers gas turbine unit 2500 hp which will be operated only when the ship is at full speed.

The equipment consists of a power turbine and a gas-generator turbine with a 9 stage axial flow. This unit can start dead cold and reach maximum speed in two minutes, which the gasoline engines cannot do. The turbine unit (73) has more favorable torque characteristics, a high torque being transmissible to the propeller at lower speeds There are other advantages to the gas turbine unit which makes its operation attractive. (a) improved ability to tow, (b) greater ease and rapidity to reach maximum speed: (c) reduction of noise compared to a gasoline engine, (d) improved reliability and less maintenance Naturally there are less attractive features connected with the operation of this new unit. The engine does not operate in reverse although it could be designed to do so Furthermore, all gas turbines require a large volume of air Such an intake unit has been installed in a protected part of the vessel. It remains to be seen what the effect of stormy weather will have on the intake of salt-laden air into the equipment

The selection of materials for operation at elevated

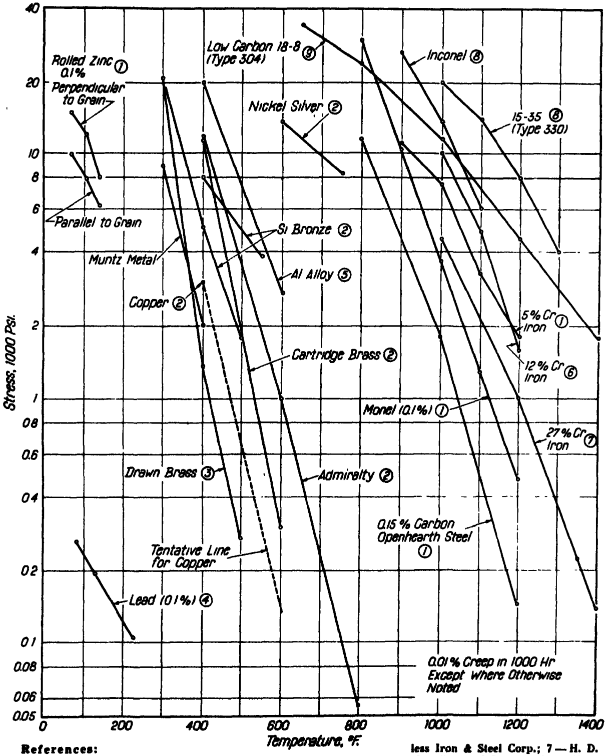
A cold rolled and hardened conveyor band produced by Sandvik Works, one of Sweden's largest iron and steel companies.

Testing a propeller blade by X-ray at the Bofors Works in Sweden.

Creep Data for Nonferrous Metals

and High Alloy Irons

Kelvin Sproule



References: 1 — National Bureau of Standards Circular C447; 2 — "Copper and Copper Base Alloys", by Wilkins and Bunn; 3 — *Proceedings* of the American Society for Testing Materials, V. 42, p. 672; 4 — *Transactions* of the American Institute of Mining and Metallurgical Engineers, V. 143, p. 166; 5 — *Proceedings* of the American Society for Testing Materials, V. 35, p. 223; 6 — Pamphlet by Rustless Iron & Steel Corp.; 7 — H. D. Newell, *Metal Progress* Data Sheet (1946) No. 95; 8 — C. T. Evans, Jr., *Metal Progress* Data Sheet (1946) No. 97; 9 — C. T. Evans, Jr., *Metal Progress* Data Sheet (1946) No. 98.

temperatures is influenced by the designer who has consistently raised the operating temperature of the gas turbine to attain greater efficiency. During the early stages of the war when mass production of the aircraft turbo-supercharger was underway, materials were selected to withstand temperatures of 1200 to 1300 deg F. Today gas turbines for power units and for gas generators in both aircraft and stationary equipment call for operating temperatures of first 1500 deg F and then 1800 to 2000 deg F. Research for suitable materials has run the gamut of a wide variety of metallic alloys including less readily available metals as cobalt, tungsten and columbium. Non-metallic refractory materials such as silicates have been investigated widely and more recently the high melting, heat-resistant metallic borides and nitrides have been the subject of intense investigation

Methods of testing at elevated temperatures are still in the controversial stage although creep testing has been carried on for a good many years The extensive experimentation during the war under sponsorship of several United States wartime agencies was published in 1947 An evaluation of the results is now possible Several symposia have been held on requirements for materials for gas turbines in America under the auspices of the American Society for Testing Materials and the American Society of Mechanical Engineers in Europe under the British Iron and Steel Institute at Zurich (63, 73, 96).

Methods of testing materials at elevated temperatures comprise short-time tension testing, creep testing, creep-rupture testing, and a slight amount of fatigue testing The short-time tension test consists in raising the temperature of a tensile specimen to the desired temperature and determining the load at which it breaks Its chief advantage lies in the fact that it offers a rapid means of selecting a group of materials that warrant further study (62) In the past much testing was done by this method in the hope that the results obtained so quickly would give useful information regarding service life at elevated temperature However, experience has shown that the test is not reliable and it is generally no longer used except for quickly surveying a field

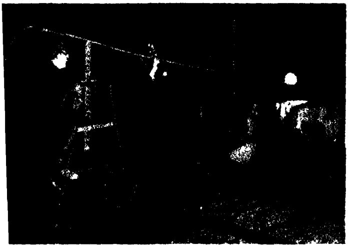
On the other hand, the measurement of creep of metals has been carried out for many years and the data collected cover a wide field of alloys and temperature range Creep is a characteristic property of all metals and is defined as the continuous deformation which occurs when a metal is subjected to loading. Each metal or alloy has a temperature range at which creep occurs. For lead, tin, and zinc, creep takes place at room temperature when these metals are subjected to loading With the metals aluminum and copper, creep occurs at slightly elevated temperatures In the case of iron and nickel, creep occurs when these metals are stressed at temperatures above 650 deg F. Alloys used in blades for gas turbines are subjected to stresses induced from rotations of about 20,000 RPM, to the corrosive effects of hot gases, and to temperatures at least as high as 1300 deg. F. Under this combination of stress and elevated temperature, creep should be held to a minimum to prevent distortion and breaking of the blade

Creep testing has been conducted for many years both here and abroad and its results can now be evaluated within certain established limits The method consists in measuring strain imposed on a specimen over a period of time at constant load and constant temperature Charts are usually shown plotted as the log of the stress versus the log of the time at several different temperatures The use of log-log charts for plotting these figures is for the purpose of presenting a straight line (63 to 85), but more recently this custom has been criticized As information on creep testing has appeared in the literature, a basis for evaluating long-time testing methods will likely be evolved. In discussing creep behavior at Zurich in July, 1947, Con-

Electronic pinhole detector automatically spots, classifies and marks holes smaller than 1/64 in. in tin plate a 1,000 ft. a minute.

Taking photomicrograph of the surface of a Kingsbury thrust bearing for a large vertical water wheel generator.

End view of open hearth main burner, showing packing glands for expansion of non-ferrous oxygen tube and expansion of fuel pipe casing.



An oxygen lance is used for decarburisation in a steel mill.

View of a high-purity liquid oxygen producing interchanger.

way claimed that the use of the double logarithmic method of plotting is liable to error. Furthermore, he stated that there is no basis for extrapolation of creep behavior into the future (80) which has been a common practice since the production of gas turbines cannot wait ten years for the results of creep testing.

Carrying out any precision testing at elevated temperatures is liable to serious error and creep testing is no exception to this rule. Temperature fluctuations in any one laboratory may be held to 2 to 3 deg. C. but variations among commercial laboratories have been found to be as much as 15 deg. C (80). Such a situation makes much of the existing data on elevated temperature testing questionable. For example, if in any one laboratory two different creep tests show a temperature fluctuation of 2 to 3 deg. C. due to thermocouple calibration and temperature fluctuation over the test piece, this variation can give a 30 per cent error in the time it takes to reach some selected elongation.

Other errors in creep testing are the non-uniformity of cross section of the specimen and the difficulty of maintaining true axial loading to give about the same magnitude of error as that caused by the temperature. It was suggested by Conway (80) that a plot indicating linear stress against log time could be used to map out the probable scatter band. A further warning was given to point out structural changes in the material undergoing test which might well prove fatal for the use of the material. If on the stress versus log time curves there is evidence of a progressive declination from a straight line outside the scatter band and towards the abscissa, then the quality of the material itself should be exhaustively examined at the end of the test.

Today it is customary to present design curves which show the transition point from second to third stage creep and various amounts of total strain from 0.1 per cent to 1.0 per cent. These data are obtained by running horizontal lines across the strain versus time charts at the desired total strain values.

Stress-rupture testing resembles creep testing but it is carried through to rupture. This method is now widely used and quite considerable published data is available as well as laboratory equipment commercially developed to carry out the testing.

The list of alloy compositions suitable for use at elevated temperatures is very extensive. A simple group classification is as follows (64): (a) Age-hardenable wrought alloys, (b) Work-hardenable wrought alloys; (c) Age-hardenable cast alloys, (d) Cast alloys normally used as cast, that is, not heat treated.

Improved physical properties at room and high temperatures are developed by solution treating and aging groups (a) and (c), as well as by work-hardening those of group (b). Such practices may offer advantages for the short life encountered in airplane structures, but these effects may be lost for long-time service required in stationary gas turbines. Many alloys in all groups lose much of their available ductility over an extended time.

It is difficult to classify these refractory metals on a basis of their alloy content as the variation is so great. In general the modified stainless steels are suitable for use at 1200 deg. F., and the cobalt base, nickel base, and nickel-chromium-cobalt base alloys are suitable in the 1300 deg. F. to 1500 deg. F. range. An investigation of certain chromium base alloys, which resulted in extremely high rupture strengths (99) at 1800 deg F, has opened this group to further study although excessive brittleness has posed serious problems.

Much work remains to be done regarding the physical metallurgy of alloys for elevated temperature service Identification of the metallographic constituents by special etching reagents and chemical attack to dissolve preferentially certain constituents, which can be subsequently identified by chemical analysis or by X-ray techniques, are being investigated at the present time Little is known regarding the structural changes taking place during stress at elevated temperatures although continued precipitation of microconstituents is often observed

Much has been written regarding the role of cast versus forged alloys Both laboratory and field service tests indicate that forged materials have superior endurance strength at temperatures in the range of 1200 deg F However, cast materials are comparable in endurance strength to forged materials in the range of 1500 deg F At higher temperatures and for longer duration, the stress to rupture values are superior for cast materials.

There is also evidence that casting offers certain economical advantages over precision forging which is necessary to produce accurately turbine blades in order to eliminate finish machining Forging of alloys to resist deformation at elevated temperatures is slow and the life of forging dies is short As precision cast methods become cheaper, the use of cast turbine parts should increase.

Welding research for the commercial alloys developed for gas turbines has been extensive For the most part welding can be accomplished by arc, resistance, gas, or shielded arc methods In the case of Inconel, electrodes have been used for welding the alloy to itself (61 to 120).

Materials for Hard Facing

The building up of surfaces subject to severe wear with special alloys of high hardness and toughness is a growing industry Improved materials and methods of application are becoming more available An outline of alloys suitable for welded surfaces has recently appeared. Hard facing materials may be classified according to their uses (169):

Group (a). For abrasion and impact, welding rods which can be hot forged are made of 7 chromium, 3.5 manganese, 1.5 carbon which contains austenite for heavy impact resistance, and chromium carbide for abrasion resistance. It has a hardness of Rockwell C 55. This alloy has been successfully used as a hard facing on carbon or manganese steel for the maintenance of crushing machinery and to reduce costs of repair. It has also been found advantageous for facing of hand picks and tie tamper bars as the ends can be forged. Other applications are for steel mill wabblers, coupling boxes, railroad frogs, etc.

Group (b). Where a polished surface is required to resist abrasion an alloy of 33 chromium, 7 manganese, 4 carbon with small amounts of silicon and zirconium has been found useful due to the presence of chromium carbide needles It has a hardness of Rockwell C 56 to 58. When applied to plowshares, the wear has been reduced 5 to 1. It has also been used on cement mill drag chain links

Group (c). The first type in Group (c) finds use for heat and corrosion resistance and the second type has even higher hardness but is weak on impact With the first type, the microscope reveals a structure of a light constituent, tungsten carbide and a gray constituent, a complex chromium carbide, surrounded by a white matrix of cobalt with chromium and tungsten in solid solution The material has a hardness of Rockwell C 44 and can be machined by sintered tungsten carbide tools. It is satisfactory for use at elevated temperatures under high impact as for example in automotive exhaust valves where the cobalt matrix resists shock During World War II it was used on aircraft valves and has found peacetime application for large diesel engine valves, railroad locomotive valves, and such places where hot gases are involved. This material has been used to build up hot punches with a backing of S A E 1045 steel, with a reduction in price of the built-up tool Composite construction is also suitable for hot shear blades, hot forming and trimming dies subjected to impact, and other places where high pressure, abrasion, and elevated temperatures are expected

The second type alloy in Group (c) contains more tungsten carbide with a resultant increase in hardness to Rockwell C 54 Hard facing applications are expeller screw segments and sleeves for centrifugal pumps

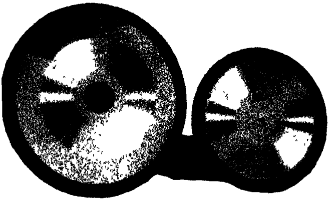
Group (d) One of the most severe requirements lies in earth cutting equipment where the tool must have a polished surface to resist abrasion In the Group (d) classification, cast tungsten carbide is fused into a steel matrix with resulting hardness of C 90. Such a surface finds use in rock bits for drilling, scarifier teeth used in roadbed work, and coal cutter bits

NON-FERROUS PHYSICAL METALLURGY

General Survey

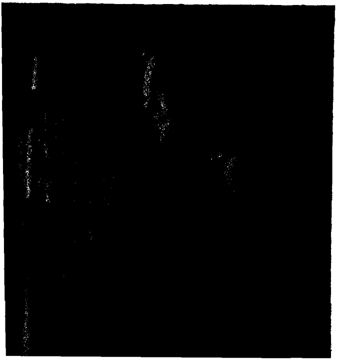
Non-ferrous metals produced in the United States represent less than 10 per cent of the total metal production of the country. It is expected that the slight increase in production in 1947 was due to the growth of aluminum and magnesium. Production of the light alloys has made a good showing since the war (121). Productive capacity for aluminum is approximately 1.25 billion lbs. per year. In 1946 it was over 800 million lbs. and for 1947, it is estimated as of December 1, 1947, that it will be 1.20 billion lbs.

The first electronic frequency converting equipment in United States for the production melting of alloy steels.



An electroformed phonograph "mother" and "stamper" made with nickel.

This apparatus, called the "vacuum carbon train," determines the carbon content in steel when it is .005 of 1 per cent or less.



For magnesium, the outlook is not so bright because estimates for 1947 are 25 million lbs. whereas capacity is 212 million lbs. It has been suggested that a large financial investment in continuous rolling mills would place magnesium sheet on a competitive basis where it could readily undersell aluminum by reason of its better machining properties. The Magnesium Association reports that since the end of the year, 71 new uses for magnesium have been found.

Interesting is the development of aluminum sheet for roofing, especially in the southwest where 400,000 roofs for farm buildings have been installed. The climate in this section is ideal for exposure of this material

A report on wartime advances in Britain (122) mentions the wide use of aluminum bronzes (10 per cent aluminum, 5 iron, 5 nickel) for aircraft and ordnance for applications requiring high strength and resistance to wear and corrosion This alloy could be arc welded with the use of coated electrodes.

Free machining copper with 0 5 per cent tellurium found use in a magnetron valve for radar because of its high electrical conductivity and the close tolerances obtained on machining Copper-lead bearings were developed for internal combustion engines and could be successfully manufactured by casting, electrolytically, and by powder metallurgy Welding electrodes were made of a copper-chromium alloy Copper containing small amounts of beryllium were used for precision parts, but with the end of the war the cheaper alloy of copper-nickel-manganese is finding its place

Corrosion of condenser tubes was ameliorated in the main condensers of naval and merchant ships by the addition of 0 5 per cent iron to cupronickel (70 copper, 30 nickel) High temperature heat exchangers were made of aluminum brass with a small amount of arsenic (76 copper, 22 zinc, 2 aluminum).

Copper and Copper Alloys

A method of identifying the delta constituent in aluminum bronze (125) recommends the aging for 9 days of the standard ammoniacal peroxide in order to darken this phase.

A worthwhile research program has been undertaken by McAdam (56 and 123) to extend his fundamental testing of materials ranging from ferrous materials to copper, copper alloys, monel metal and high purity aluminum. He reports the effects of combined stress and low temperatures on notched specimens in tension testing The mechanical properties of a metal involve plastic deformation, resistance to fracture, ductility, and total work, of which the first 3 are studied here. He points out further that the resistance of a metal to plastic deformation is a function of 3 principal stresses and that the resistance to fracture depends on the limiting value of the greatest principal stress and varies little with the temperature or rate of deformation. The influence of notches on the above properties is given in a series of charts.

Aluminum and Aluminum Alloys

For many years in England the problem of precipitation in aluminum alloys has been thoroughly investigated both theoretically and experimentally. A large body of literature is now available which has helped to clarify certain aspects of this phenomenon (128). In particular an aluminum alloy with 4 per cent copper has received special attention Its composition is simple and the changes involved are fundamentally important To sum up present theories, precipitation as it is recognized in alloy systems can occur in a continuous or a discontinuous manner

Discontinuous precipitation is characterized by a preferential precipitation in grain boundaries which generally spreads inward Precipitation within the grains is non-uniform. On X-ray diffraction photograms, faint lines belonging to the new solid solution gradually appear as aging proceeds These lines increase in intensity while those of the original solid solution decrease in intensity as shown in alloy systems of (a) aluminum with 7.5 per cent copper aged 5 minutes at 615 deg C and (b) aluminum with 4 per cent copper aged 5 minutes at 130 deg C.

Continuous precipitation is characterized by more or less uniform precipitation throughout the grains at much the same rate everywhere without regard to grain boundaries. An example is that of an aluminum alloy with 4 per cent copper aged 21 days at 250 deg C The lattice parameter changes regularly from that of the original solid solution until it corresponds to that of the new solid solution

In contrast to the above theory, Mehl and Jetter (129) state that continuous precipitation is the simple type while the discontinuous is anomalous For example, in nickel containing beryllium, continuous precipitation occurs at a high temperature and discontinuous at a lower temperature In a study by Jones, Leech, and Sykes of silver-copper alloys at the silver rich and at the copper rich ends of the phase diagram, it appears that precipitation is continuous at the higher temperatures when supersaturation is low and the reverse at lower temperatures (130)

However, Gaylor claims that in aluminum-copper alloys discontinuous precipitation is not anomalous, but precedes continuous precipitation (128) The factors involved are as follows: (a) the degree of supersaturation of the solid solution, (b) the temperature at which precipitation occurs, and (c) the time at temperature It should be noted that both types of precipitation take place in aluminum-zinc alloys.

If supersaturation is critical in controlling the onset of continuous precipitation, it should have a practical bearing If two alloys are aged at the same temperature, but one has a higher per cent of solute atoms than the other, then continuous precipitation should set in earlier in the alloy of lower concentration. The reason for this is that the critical degree of saturation is reached sooner. If a higher aging temperature is used for these two alloys, it is possible that continuous precipitation will occur sooner in one alloy than the other. The alloy containing less of the solute will over-age or soften more rapidly than the other. It also seems probable that discontinuous precipitation will occur where conditions of strain predominate and continuous precipitation where there is little or no strain. In the aluminum-copper system, the situation is further complicated by the presence of an intermediate precipitate designated as "alpha $CuAl_2$" to differentiate it from a subsequent compound termed "beta" Other alloy systems have shown indications of forming intermediate phases during aging and only after softening sets in does the equilibrium phase appear

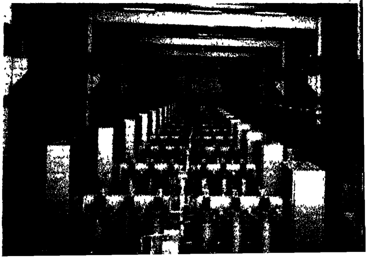
The nature of precipitates formed in early stages is almost entirely unknown since methods of study of such hardness and X-ray diffraction techniques do not lend themselves to detect such changes The only reasonable approach is that of the microscope and it is hoped that investigations will be conducted along these lines

In a study of the aluminum alloy 61 S-W containing 0.25 copper, 0.6 silicon, 1.0 magnesium, and 0.25 chromium, it is reported that in sheet form the rate of precipitation is accelerated by cold work prior to aging In this alloy the hardening agent has been identified as Mg_2Si (131)

Heat treating schedules for aging a number of aluminum alloys requiring different periods of time have been revised to save handling and space (132).

Disposal of high-production war surplus assets such as this magnesium plant poses problems for light metal industries.

Mercury-arc rectifiers afford efficient means of converting alternating to direct current for many industrial uses.



Magnesium and Magnesium Alloys

In a recent survey of the Japanese magnesium industry (136) that started with the erection of the first plant in 1933, the rapid expansion which followed could only be explained by plans for war. In 1945 there were 15 plants producing magnesium by several processes. At the Ube plant of the Riken Metal Manufacturing Co., production was based on a raw material of natural or bitter brine. The composition of this was, $MgCl_2 = 17.62$ per cent, $MgSO_4 = 6.48$, $KCl = 2.88$, $NaCl = 3.55$. At Asahi, I. G. Farbinindustries established in 1937 a plant based on magnesia and charcoal reduction with the use of chlorine gas. In Korea, the Nitchitsu Manufacturing Co. set up a plant to produce magnesium by the carbothermic or Hansgirg method, similar to that undertaken at Permanente, California. This process depends of the high temperature reduction of magnesium oxide by carbon with rapid condensation of magnesium powder in a stream of gas. The powder is remelted and cast into ingots. Although trouble was experienced at Permanente, the Japanese attained a production of 3000 lbs. per day.

It is interesting to observe that the magnesium in Japan contained considerable impurities compared to that in the United States. It could never have been used as a substitute for aluminum alloys. However, it was suitable for alloying with aluminum and for use in pyrotechnics and was also satisfactory for castings such as aircraft landing wheels, for instruments, and engine parts.

In an attempt to prevent the occasional burning of magnesium alloys during heat treatment, a study on furnace atmospheres indicates oxidation takes place in two stages at temperatures below the apparent melting point of the alloy being treated (137). There is first a slow initial oxidation (exothermic) and then melting and rapid oxidation. The temperature at which the original oxidation leads to burning is dependent on the composition of the alloy, the moisture content of the gas, and the velocity of air over the furnace charge.

As an alternative to the foregoing, the addition of beryllium to magnesium (142) to the amount of 0.001 per cent greatly reduces this tendency to burn. In casting these alloys, the presence of beryllium eliminates the use of fluxes and the foundry sand need contain no inhibitors. In the magnesium alloy AZ 92 containing 9.3 aluminum, 1.8 zinc manganese, 0.0051 beryllium, and 0.030 iron, the presence of beryllium tends to precipitate iron and manganese from the melt. The most detrimental property of beryllium is that it tends to coarsen the grains of the magnesium alloys.

During the war, the Germans developed a magnesium alloy EM 62 containing 6 per cent cerium and 2 per cent manganese which had better creep resistance at 550 deg. F. than the well known Y alloy (139). Since the war, a new magnesium alloy has been reported with the composition of 5.8 per cent zinc and 0.80 per cent zirconium remarkable for its fine grain, toughness, and its ability to be extruded at high speeds (141).

A study on the nickel-beryllium system indicates that alloys of this series age-harden more readily than those of the copper-beryllium group (145). With nickel containing 2 per cent beryllium, maximum precipitation occurs after a few hours at 900 deg. F. With 1.6 per cent beryllium, age hardening at 900 deg. F. for 4 hours results in an alloy with a hardness of 460 Brinell, a tensile strength of 250,000 lbs. per sq. in. and a yield strength of 100,000 lbs. per sq. in. On this material a fatigue strength of 65,000 after 30 million reversed cycles of stress was obtained and a corrosion fatigue strength at 1450 rpm of 30,000 lbs. per sq. in. after 30 million cycles of stress was found.

A new magnetic alloy is reported with the composition of 79 nickel, 5 molybdenum, 15 iron, 0.5 manganese called supermalloy which can be vacuum melted and poured at atmospheric pressure in helium or nitrogen (146). It may be hot or cold rolled to 0.00025 in. The heat treatment to produce the required magnetic properties consists in maintaining it at 1300 deg. C. in dry hydrogen and cooling through the range of 600 to 300 deg. C. at a critical rate depending on its composition. In the form of sheet 0.014 inch thick the initial permeability is 50,000 to 150,000 and the maximum permeability 600,000 to 1,200,000.

A significant study has been reported on a series of zinc alloys with small amounts of copper and beryllium. Commercial zinc hardens only slightly by cold rolling as it crystallizes rapidly at or near room temperature. Its hexagonal crystalline structure makes it line up in the direction of rolling so that its physical properties vary according to the direction of working. It was thought that alloying might improve its hardening characteristics. The problem of adding beryllium is difficult as beryllium melts at 1280 deg. C. and oxidizes rapidly while zinc boils at 907 deg. C. To solve this difficulty copper and beryllium were first alloyed and then added to the zinc. The resulting series of alloys are age hardenable and have a high enough tensile strength to give mild spring properties. It is anticipated that these compositions may find a commercial application (150).

The structure of gold-berrylium, *AuBe*, has been determined under the auspices of the Manhattan Engineering Project as forming an intermediate phase in equal atomic proportions. The crystal is cubic, close packed in structure in that the beryllium atoms have forced the gold atoms out of their normal face centered position. This lattice is similar to the *FeSi* type (148).

Indium alloys have received attention especially in regard to their microstructure since extreme softness has made them difficult to polish. For the bismuth-indium series (149) the phase diagram has been constructed to locate the liquidus and solidus and to establish two eutectics, one with 34 per cent bismuth at 72.4 deg. C., and the other with 50 per cent bismuth at 90 deg. C. In the work on the tin-indium system (147) the earlier work of thermal, X-rays, and electrical conductivity has now been confirmed by microscopic methods. A re-examination of the series by precision thermal means with indium of 99.92 per cent purity and tin of 99.98 per cent purity showed a eutectic with 48 per cent tin at 117 deg. C. The photomicrographs are exceptionally clear, especially when it is realized that these alloys recrystallize at room temperature.

A periodic chart for metallurgists has been devised with analogous properties arranged along radii, and along diameters to show more clearly relationships among different metals (179).

Testing Methods

A discussion of the characteristics of the Knoop hardness tester method for its use with extremely hard substances has been reported (159) and its use in relation to the load employed (160). The Knoop method can be satisfactorily adopted for separate constituents of microscopic dimensions, for extremely hard substances, and to obtain hardness values close to the edge of a specimen

With interest in properties of metals at elevated temperatures so keen today, methods of hot-hardness testing have appeared in the literature (156 to 158) For routine work in the steel mill, Zmeskal reports an arrangement of equipment which provides an atmosphere of nitrogen in the furnace surrounding the specimen and possible readings up to 1500 deg F The furnace tube is stainless 18-8 steel wound with 18 gage chromel wire Other parts of the equipment that must withstand heating are made of alloy 19-9 DL (19 chromium, 9 nickel, 1.5 tungsten, 1.5 molybdenum, 0.5 columbium, 0.5 titanium) The results of some hot hardness tests are as follows

Material	70° F	1000° F	1200° F	1400° F.
High speed steel 6 W, 6 Mo, 2 V ..	C 64	56	47	
Hot work steel 12 Cr, 12 W	C 47		27	
Valve steel 21 Cr, 12 Ni	C 38		26	18
Hot work steel 5 Cr, 1 Mo, 1 W	C 58	47	18	
Cold work steel 5 Cr, 1 Mo	C 64	44	25	
High strength stainless (19-9 DL) ..	C 34	21	14	1
Tungsten carbide with cobalt binder ..	A 88	88	86	83

Hardness corrections for bar stock to illustrate the effect of rounds has now been established for the Rockwell hardness scales of C, 30 N, 45 N, and A (164)

The identification of nickel or monel wire in a woven wire screen can be accomplished with no damage to the material as follows.

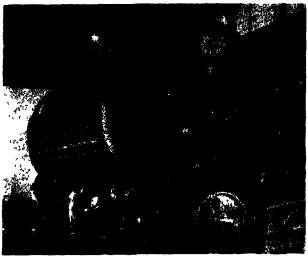
(a) Clean to remove dirt and oil Dip 2 seconds in 50 per cent nitric acid, remove excess acid. The nickel wire is coated with nickel nitrate, the monel wire with copper and nickel nitrates.

(b) Dip in 1 per cent potassium ferrocyanide and dry in air.

(c) The monel is now pink due to the copper ferrocyanide and the nickel remains slightly green due to the nickel ferrocyanide.

This test should find wide application as the usual chemical analyses are time consuming (161).

A new etchant for stainless steel and cobalt base alloys has been suggested (162) as follows: Nitric acid, 7 to 8 milliliters; Hydrochloric acid, 2 to 3 me.; Cupric chloride, 0.5 gram.



A 13 x 30 ft Pierce-Smith copper converter embodies latest improved design for this type of smelting equipment.

A punch press shaft about 6 ft long finished with heavy nickel plate.

Preparing Thermalloy casting for X-ray examination.

The polishing of tungsten for microscopic examination has been improved (163) by applying to the final velvet polishing wheel a mixture of the following materials: Linde Grade B polishing powder, 10 grams; Potassium ferricyanide, 3.5 grams; Sodium hydroxide, 1.0 grams; Distilled water, 150 milliliters

The development of X-ray diffraction equipment for studying materials up to 2700 deg. F. should find wide application for alloys required for gas turbines (166). It includes a Norelco X-ray spectrometer in which a Geiger counter replaces the photographic film formerly used. Openings in the furnace are made of beryllium sheet to provide high transmission for X-rays, to eliminate drafts, and to protect the equipment The temperature of the specimen under test can be varied at will

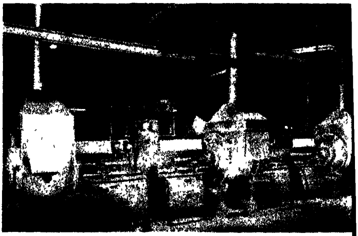
No review of testing equipment of recent design would be complete without mention of the automatic sonigage which is finding wider application as it is used (165). This ultrasonic device is suitable for both metals and plastics and has the advantage of being a non-destructive method of testing. It is possible to measure the thickness of structures from one surface only within an accuracy of 2 per cent. Flaws in the bonding of materials such as welding or brazing have always presented hazards difficult to detect. The sonigage has been able to locate actual voids in certain instances. But poor electroplating can not be detected, nor adherence of layers of babbit metal, nor depth of case carburizing

Welding and Powder Metallurgy

This review of developments in the realm of physical metallurgy does not attempt to include welding or welding methods, but the wide publicity during the war on welded ship construction has turned attention to failures which occurred with considerable loss of life, especially when the ship broke apart at sea. A report has now been officially released (170 and 171) which gives a detailed account of failures in the all-welded ships of the war years From a total of 5000 ships of the all-welded construction, there were 1000 vessels which sustained fractures of the welds Of these, 127 ships had serious breaks and 8 vessels were lost at sea In an examination of the defects, it was found that cracking started in a geometric discontinuity or notch, large or small, which resulted from poor design or faulty workmanship The crack then proceeded in a steel which was notch sensitive. This final factor is significant as it places before the manufacturer of steel ship-plate the problem of control over the peculiar condition of the material which seems to be intensified in notch sensitivity. The loss of ductility of welded structures has been ably discussed recently by Kinzel where it was pointed out that lowered ductility at reduced temperatures may well be more serious in its effects than poor ductility at room temperature (172).

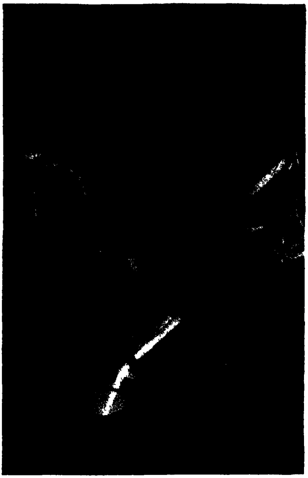
The impetus to powder metallurgy during the war was marked by a number of radical developments. The Germans, faced with a shortage of copper, manufactured rotating bands for ammunition from iron powder and reported that gun barrel wear was greatly reduced. Their consumption of iron powder during the war was ten times that in the United States. The hot pressing of tungsten carbide bullet cores at the rate of one every

General Electric's torpedo-shaped jet engines, produced for U. S. Force Force, are rolled to test chambers for trial runs.



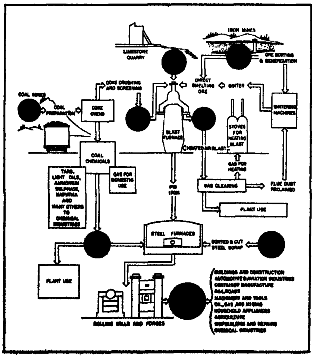
Battery of rocking electric furnaces equipped with automatic hydraulic-electric electrode control. Charging platform is situated just behind furnace.

Allegheny Ludlum's new cold rolling reduction mill turns out 800 ft of stainless and electrical alloy strip steel per minute.



Pouring a heat of Thermalloy from the large 3,000-lb. electric arc furnace at the American Brake Shoe Co.

In the flow of materials from ore mines to finished products, many processes provide economies in steel plant operations.



Melting down the charge in a 10,000 kva. 3-phase Heroult type electric arc furnace in plant of Crucible Steel Co. of America.

Droppable aircraft fuel tank is seam welded electronically.

five minutes in graphite molds at low pressure was another German process (180 to 192). In America porous nickel cups were developed as a part of the mercury switch in the proximity fuse in such a way that the spin of the shell after being fired forced the mercury through the porous nickel and caused detonation Dense parts of complicated shape pressed from iron and ferrosilicon powders were also manufactured in large quantities for walkie talkie radio sets

However, under peacetime conditions, the manufacturing of parts from metal powders must again depend on economical considerations such as the cost of powders or the unique quality of the product The importation of improved Swedish sponge iron at low cost has found a wide market It is generally recognized that the production of dense parts pressed from metal powders rests largely on the quantities of parts required even after the piece has been otherwise found suitable. Powder metallurgy is a mass production method and in this respect it is like the die casting and the precision casting industries.

Illustrations for this chapter were obtained through the courtesy of United States Steel Corp, American Swedish News Exchange, American Iron and Steel Institute, Westinghouse Electric Corp, Jones & Laughlin Steel Corp, Linde Air Products Co, Allis-Chalmers Manufacturing Co, War Assets Administration, International Nickel Co, Inc, General Electric Co, American Brake Shoe Co, Allegheny Ludlum Steel Corp, Metal Progress, Bethlehem Steel Corp.

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CHAPTER XVI

METALWORKING

by A. E. RYLANDER, F. W. WILSON, AND C. F. WORFOLK

Advances in metalworking during this post-war era are logically consistent with and supplementary to the great strides that took place during the war This article will attempt to cover the major developments, with particular emphasis upon the motives of those seeking to improve the science of producing metal products and components

One objective, always kept in mind by tool engineers, is more rapid production of parts with less effort on the part of the operator A second objective is a better product at lower cost As a result of this type of thinking, the modern machine tool is undergoing rapid changes

MACHINING

The subject of machining can be divided into several classifications

Feeds and Speeds

Extensive use of aluminum and magnesium during the war focused attention upon faster feeds and speeds than previously attempted with these materials and, in fact, lifted the sights with respect to all metals

Cutting speeds of thousands of feet per minute were possible for these two metals instead of the usual hundreds Therefore, machines were redesigned for the higher cutting speeds In some cases, such as high-speed milling, high-cycle motors were mounted directly to the spindle, and the balance of the machine redesigned in harmony with the several new problems that this entailed

More widespread use of the harder cutting materials, such as cemented carbides, contributed to a general increase in cutting speeds. As usual in any new development, the new cutting tools introduced additional problems Inherent brittleness of these tools was overcome by negative back rake angles and cushioned supports Their larger capacity for removing metal also required changes in machine designs These, in the final result, meant higher efficiency for the tools themselves so that post-war machines have higher speed ranges than formerly

Cycling

The newer machines invariably tend toward faster cycling. An example of this is the rapid traverse. Here, considerable cycle time can be saved if the work is brought more rapidly to the cutting tool Further development of the hydraulic drive has contributed much to faster traverse. The infinite variations in speed obtainable with this type of drive made it eminently suitable for both rapid traverse and feed. And in instances where the mechanism is not complicated, electric rapid traverse and feed drives cut down the cycle time

These developments led to improvements in automatic cycling, whereby rapid traverse, feed and rapid return are automatically determined These three steps are often subdivided into minor steps for interrupted cuts or variations required by the workpiece By careful study of the work to be performed, automatic cycling greatly reduces the time required for the production of each part

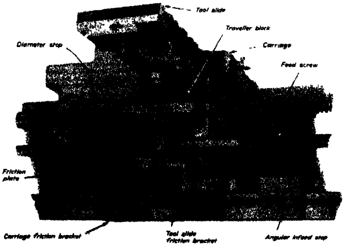
Control

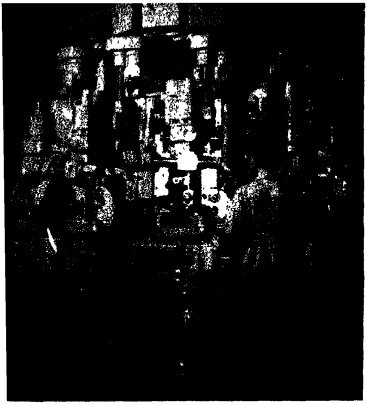
Usually the rapid traverse, feed and cutting speed are adjusted by a specialist called a "setup man." This leaves little for the operator to do except load the stock and remove the finished parts If the machine is equipped with direct-current motors, speed variations are more easily obtained When alternating current is used, speed variation may be obtained through a variable-speed transmission, a motor-generator set, electronic rectification, or hydraulic pressure variation For optimum control of each machine function, the number of motors is usually increased And if an hydraulic circuit is used, all valves are interlocked with the electric control circuit

Flexibility

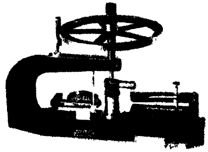
Single-purpose, high production machines require considerable capital outlay, which may be entirely lost if the part becomes obsolete So the modern trend is toward a compromise between the general and special-purpose machines Standard accessories are used as far

Feed and traverse mechanism on a double carriage lathe. Two control boxes at each end of the lathe house the mechanism for operating and cycling carriage slides.





Serving as ten machines in one, this shaper cuts gears automatically. It features automatic chip control, and has separate drive and control at each station.



Light wave micrometer uses interference fringes to establish measuring pressure, enabling readings to be duplicated to .00001 in. Such measurements are possible without gage blocks.

Seventeen machining operations can be performed on this drilling unit. Eight automotive engine blocks are carried continuously on a track and lowered into position without the operator's help.

as possible. Controls are arranged for either manual or automatic operation in order that the changeover can be made in a short time In fact, a new lathe has been introduced in which the cross-slide is entirely independent of the rest of the machine and contains its own motor with sensitive stops and rapid traverse

Multiple operations

Methods for using several tools simultaneously are being developed rapidly as the need for higher production increases Multiple cuts are used in grinding, broaching, milling, lathe work, drilling and particularly in the newest art-station work In this type of machining, work fixtures index to a multiplicity of cutting stations Each tool performs a separate operation The operators' duties consist of merely loading and unloading the fixture An example of this is a recently developed machine with 24 stations, which completely finish a refrigerator pump body

Accuracy

The tendency in most designs is toward closer tolerances and finish in order to obtain more rapid assembly and smoother operation To accomplish this, the machine tool builder is increasing the dimensions of the affected parts in order to obtain a higher order of rigidity, thereby eliminating or reducing chatter and vibration

Lubrication systems are being given considerable attention Hardened way surfaces are being used when costs are justifiable, to prevent inaccuracies due to wear Automatic control of the cutting tools is provided to compensate for the wear due to the cutting operation An example of this is seen in the control devices now being furnished on grinders The grinding wheel is automatically advanced to the control position to compensate for its loss in diameter due to the wheel wear Temperature control is being installed on machines to overcome errors due to wide variations in shop temperature or machine conditions

Service and Maintenance

For many years, machine tools were characterized by the difficulty with which they were repaired. This condition is being carefully studied and remedies applied where needed Motors are mounted for quick removal, and electric panels located for ease of maintenance Chip conveyors are installed in many machines and lubrication systems made automatic as far as humanly possible

Down time

One of the important factors in the cost of making a part is the time required to load it into the machine. In many cases, a redesigned fixture with a quick clamping device, or a hydraulic chuck, is more important than increasing the cycling or traverse speeds To this must be added the time for tool sharpening before a true picture of the total cost of the part can be determined.

Safety

Accident hazards are being continuously reduced, because they affect the production rate and the attitude of the operators. Automatic stops are being placed on planer tables to prevent run-aways. Double starting buttons are being installed, and electrical and hydraulic systems interlocked to prevent mishandling Even the lubrication systems are being installed so that pressure must be built up before the machine can be started so that the spindle gets a supply of oil before the machine turns over Punch presses are now equipped with gates or sweep arms to prevent needless accidents

BROACHING

(1 to 15)

The art of broaching has been subjected to considerable refinement in the past decade As an example of what can now be produced, a broach has recently been manufactured for cutting the 33 involute splines in steel clutch driving plates The broach is 5⅞ in in diameter, 63 in long, and weighs 370 lbs Approximately 17/32 in of stock is removed in one pass, and the production rate is 120 pieces per hour

In operation, the workpiece is placed on the table of a vertical hydraulic broaching machine The upper tool carriage lowers the broach, with the shank accurately centralizing the clutch plate Then, when the broach enters the automatic puller on the lower side, the main slide pulls the broach downward through the part At the end of the downward stroke, the part is removed and the broach returns to its original position All motions are controlled by pushbuttons for complete cycling

Surface broaching is being used considerably, particularly for such parts as aluminum outboard motor parts The broaching machine consists of a table containing a shuttling device which moves the workpiece and its fixture from side to side in front of the two broaches In some cases, the fixture is for single parts and the table shuttles the device or fixture from the loading position to the working position and back, in synchronism with the single broach which travels vertically

Control of these cycles is an important element in the operation of these machines A selector switch is furnished that can be set for automatic, semi-automatic or manual control of all functions For safety, the operator must press both starting buttons at the same time and, in case of necessity, a knee bar has been installed that stops the machine instantly "Inching" buttons are furnished, and limit switches can be connected in series with each coil circuit, or in combinations of series-parallel limit switches for desired machine operation

The horizontal broaching machines have the advantage of being easy to set up and can be obtained in capacities of from 2 to 20 tons and with strokes up to 66 in They are particularly adapted for internal broaching, although some external work can also be done Broach speeds can be varied from 15 to 29 fpm, and these figures cover most requirements

DRILLING

(16 to 36)

Because drilling is probably the most common of machine operations, a great deal of engineering thought has been devoted to this subject.

The development of the hydraulic drilling unit has opened up what amounts to an entirely new field in the design of drilling equipment. These units consist of a motor driven hydraulic pump and spindle. The hydraulic circuit can be arranged for electric start and

This Gisholt turn-mill takes a complete crankshaft, removes excess metal from the counterweights, and mills the crankpin diameter in 55 seconds. Only a single operator is required.

$100,000 gear shaper which was sold from the floor on the second day of the 1947 Chicago Machine Tool Show. Shown inspecting it is an official of the National Railways of Colombia.

This 15-ton radial drill typifies trend toward specialization evidenced at the Machine Tool Show held in Chicago, September, 1947. Despite its size, the machine can be moved with one finger.

rapid approach All speeds are infinitely variable and all feed rates are also adjustable The device is easily installed and easily rearranged when production needs vary As a result, it is possible to use the units over and over again, thereby spreading the original cost over several years

There are two schools of thought on multiple drilling One method is to drill all the holes at once with the work set up in a single position These holes are drilled in several directions, using hydraulic units and holding the work in a standard fixture An example of this is the drilling of 98 holes in a tractor crankcase assembly.

Another type of multiple drilling uses rotary tables in which the table is indexed from station to station, coming successively under a series of tool spindles or heads. In these machines it is not necessary to confine the machine to drilling, reaming and tapping Operations such as counter-boring and chamfering can be added, if required.

Still another type of drilling machine uses a horizontal drum indexing mechanism One design has a 10-station hydraulic indexing drum and is used for drilling and taper reaming The horizontal spindle unit has 34 spindles and is hydraulically driven.

Drilling is often combined with other operations in the same machines As a safety feature, all units are hydraulically interlocked so that all units must perform their operations and return before the fixtures can be released and the transfer bar operated Failure of the clamping, unclamping, transfer, or operating units to perform during any part of the cycle can readily be detected by means of a system of lights shown above the pushbuttons in the control panel

The transfer machine consists primarily of a conveyor, and the workpiece is carried from station to station, usually in a straight line One very successful setup turns out refrigerator compressor bodies at the rate of 188 pieces per hour Two workpieces in a single fixture are conveyed through 24 stations while 31 different operations are performed using 152 tools

This type of machine is also used in the manufacture of automobile frames which completely finish the frames from the raw material state and include many different types of operations, such as welding, riveting, drilling, reaming, facing and rolling While the cost of these machines is great, their capacity for extremely high rates of production offsets the high initial investment

Most automobile manufacturers are currently installing transfer machines for a variety of purposes

Aluminum sheet is lowered into sulphuric acid bath. Electrolytic oxide film deposited produces brilliant finishes and better corrosion resistance.

Differences in degree of buffing become apparent after anodizing. After material has been buffed, it is dipped in a caustic cleaner bath and rinsed.

A number of drilling accessories have recently been developed for improvement of drilling techniques The adjustable multi-spindle drill head comes under this classification Each drill head can be revolved about two different centers so that the drill point can be located and locked at any point in the area of a 3¾ in circle The drill press turret also increases the usefulness of the drill press. One type has a three-position turret head which can be arranged for drilling in one position, tapping in another and chamfering in the third The tapping head is reversible and uses a collet-type chuck

On low production work, the designer is often faced with the problem of accurately locating holes where the rate of production does not warrant the cost of a drill jig To solve this type of problem, a new device has been created The hole spacer consists of a heavy flat table which moves laterally or longitudinally under an accurate spindle fixed rigidly in one position

With the work clamped in place, the table is hydraulically traversed from one predetermined position to another by two selector controls Once the stops have been set, the table will return to them with high accuracy This device can be mounted on a radical drill press since an arm is furnished from the bed of the spacer to the arm of the drill

Aluminum thermos jug castings, buffed and racked for anodizing of 25 min. at current density of 12 amps per sq ft.

FINISHING

(37 to 51)

Many industries have arrived at an entirely new conception of metal finishing

Due to their experiences in producing war products, today's finishing of metal goods is vastly superior to that of five years ago

Rapidly disappearing is the assumption that one cleaning method is satisfactory for all work Each metal being cleaned, each substance being removed and each process being followed has a decided bearing upon the type of cleaning employed and the method of application Increasing use of zinc, aluminum, copper and magnesium makes it impossible and impractical to apply one cleaning method to all production

Electro-cleaning has long been considered the only way to obtain a chemically clean surface Despite recognition of this fact, there has been some resistance to its wider use because of unpleasant working conditions involved Recent developments provide for a dense, shallow, foam blanket that prevents overflowing, fuming and explosion In many cases, anodic cleaning eliminates a precleaning operation, but many plants will continue the use of a degreasing, tumbling or washing operation before plating

Electro-chemical descaling may well be the most important descaling method in tomorrow's plant, especially where no dimensional changes can be permitted An advantage of the method is the ability to remove scale in recessed locations

Degreasing is being used more frequently as an intermediate operation This operation removes most oil-bound metallic and abrasive particles that might damage dies and tools used later Solvent degreasing is expected to find an increased use in all types of operations because non-flammable, chlorinated solvents are now available that can be used in the three degreasing systems vapor, spray and immersion

Pickling of non-ferrous sheets will be done continuously in the plant of the future A recently developed spray-pickling process speeds the pickling operation by eliminating the dipping of sheets and results in a bright surface finish

Develoment of black oxide finishes is one of the most important advances in recent years. These finishes can be applied to copper and copper alloys, zinc, steel and tin by a simple method Metals so finished have a permanent jet-black surface The finish does not alter the characteristics of the metal nor change its dimensions or hardness It has lubricating qualities which make it suitable for sliding surfaces or parts which must be run in.

The value of porcelain enamel as a finish has long been recognized for many products, but its use is now being extended and may even be applied to aluminum in the future. The difficulty with chipping has been minimized through the use of better ferrous material and improvements in pre-firing methods. This type of finish is particularly important from the standpoints of eye appeal and abrasion resistance.

Alkali-alumina coatings are a more recent development These are applied by spraying or dipping and then baked on the metal rather than being fused with it They are corrosion resistant, partially acid resistant, and heat resistant up to 800 deg F

Electro-plating has also taken some forward strides, especially in the development of new electrodes for zinc and lead deposition A particular development is the use of oil-bearing chromium Control over the process results in a deposition containing small pockets of regular shape which hold lubricating oil A special application is in cylinders for diesel and gasoline engines

Chrome plating of tools is becoming more popular as its practical advantages are recognized This is especially true in the case of expensive form tools and broaches where two or three platings can extend the tool life many times Its use on gage blocks has demonstrated the versatility of this material

FORGING

(52 to 65)

Forging practice has considerably improved as the result of war production requirements, and these developments will naturally be extended in fuller peacetime applications Modernization of equipment will prove a big factor in extending the use of forging to many fields hitherto unexplored

Advances that have been made in forging consist of better heating of billets, bars and blanks, more scientific and better design of dies, improvement in closed-die techniques; an increase in the general knowledge of the metallurgy involved. and ability to produce forgings with little flash.

Scale has been one of the greatest drawbacks to the forging method It ruins the dies and is often pounded into the part, ruining it

The elimination of scale is being attempted by better heating practice Controlled atmosphere furnaces, induction heating and molten heating baths of various types are now used in the forging field to heat stock before forging.

Recent tendencies in forging move towards a reduction in the amount of metal to be used. An example of this is a railway axle which was formely forged solid Under the new method, it is forged from a seamless tubing These new axles have been very successful because they provide strength where needed and are considerably lighter

The forging of aluminum has opened up an entirely new field Aluminum cylinder heads of radial aircraft engines were made as castings for many years Press forgings have replaced this method of fabrication And because the new heads increased the horsepower ratings, the entire engine could be redesigned for a higher horsepower to weight ratio

An addition to forging methods is known as centrifugal forging The steel bar is rotated in the dies during reduction so that the excess metal is extruded into a gate rather than being forced into a flash gutter surrounding the die impression This results in a forging which has no flash or parting lines The method is now being used to produce parts such as piston pins and is specified to control grain flow and eliminate cracking in later heat-treating operations

The use of closed dies has lately been developed to the extent that complicated shapes can be produced more readily Within limitations as to size and shape, forgings of brass, copper and aluminum are being produced economically, chiefly because of the extrusion qualities of such metals Formerly, closed dies were used chiefly on simple shapes, usually symmetrical.

At present there is a tendency to combine forgings and stampings, through welding and brazing, thereby saving weight but obtaining great strength

GRINDING

(66 to 81)

The closer tolerances and finer finishes now generally specified make grinding and its allied operations—honing and lapping—of increasing importance Major improvements in this field include:

(a) *The automatic sizing of cylindrical parts.* One means of accomplishing this is through the use of electrical gage heads which determine the grinding operation by direct measurement of the work being ground. At the same time, an indicating meter provides visual

Three meter magnets are copper plated electrically in the same solution by different methods. Magnet at left was current racked-plated for 5 hrs; center was direct-current barrel-plated for 7 hrs; and left was periodic reverse-current-plated for 4 hrs.

Toolroom grinder has hydraulic mechanism for an unlimited number of longitudinal table speeds from 6 in. to 50 ft. per minute.

inspection for size Sizing automatically may be applied to longitudinal measurements as well as to diameters. For example, if grooves or shoulders are to be ground, their location can be made part of the automatic control equipment

(b) *Contour grinding* By this method the wheel is dressed to the inverted shape of the workpiece, after which the wheel can be used to turn out a large number of identical parts before requiring redressing

(c) *Crush forming of contour wheels* In this process, a steel wheel having the same contour as the workpiece on its outside diameter, is machined and hardened The roller is then mounted on a wheel crushing mechanism built into the grinding machine or furnished as an accessory The roller is forced into the surface of the grinding wheel by power or hand, breaking down the bond and reproducing its own shape in the wheel This method can be used for both cylindrical and surface grinding

(d) *Improved diamond wheels* Large savings of labor have been made in the grinding of optical glass such as prisms These wheels make it possible to grind to a finish and flatness suitable for final polishing They are also used to grind hardened die and tool parts and similar parts made of cemented carbides

(e) *Increased emphasis on surface finish* It is found that the coolant for grinding, lapping and honing must be really clean This necessitates an efficient means of removing metal and abrasive grits from the coolant as it is recirculated through the machine An automatic separator of the magnetic type has been developed for this purpose which removes the sludge from the coolant Improved filter presses are also used, particularly for batteries of machines

Grinding machine design has made rapid strides, particularly with respect to the spindle bearings One company has developed a very successful spherical bearing which permits some measure of self-alignment and, because of its split construction, can be adjusted for wear Another type is the hydraulic wedge type In this type of bearing, eccentric wedges are located about the spindle shaft in such a manner that the oil in the bearing is forced into radially tapered pockets, thus forcing the shaft into a centrally maintained position

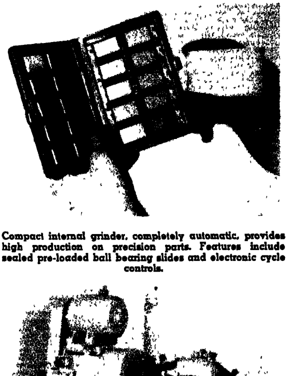
Headstocks are now being supplied with variable speeds, and spindle drives on surface grinders are being equipped with V-belts instead of the older flat belts. Feed screws are mounted on pre-loaded bearings, and automatic back-lash take-up is usually furnished on the more advanced equipment.

On internal grinders, the grinding fixture is so arranged that it can be swung out of the way when loading and unloading, a particularly advantageous improvement under certain conditions. Tarry, or dwell, adjustment at either end of the table is now regularly furnished on modern machines, as well as built-in leveling screws.

Many improvements have been made in the design of the crankpin grinder. An entirely new cycle has been developed which consists of the following steps: (a) Grinding the sidewalls of the pins is controlled by the dashpot feed, after which the pin feed begins This feed is operated from a hydraulic cylinder built into the feed-up arm At a point where the pin is about 0.015 in. oversize, the feed stops and a short cycle rounding-up action takes place (b) The operator places the sizing device on the crankpin and thus releases the slow grinding feed At this point the back rest is positioned against the pin under regulated pressure The first sizing contact reduces the pin feed to a finishing rate, and the second starts a timer, which retracts the wheel and resets all feeds to their original position

On camshaft grinders, the grinding was formerly done in both directions of traverse The net result was that the cams at one end were larger than at the other end due to wheel wear The newer machines grind in one direction only and the wheel is redressed while the carriage is resetting This is made possible by a modification of wheel dressing equipment which has been separated from the traversing mechanism

Sets of stainless steel machine cut standards prepared for tactual comparison of machine surfaces. Such standards provide a positive method of determining acceptable surface roughness.



Compact internal grinder, completely automatic, provides high production on precision parts. Features include sealed pre-loaded ball bearing slides and electronic cycle controls.

The valve face grinder, equipped with a compact hydraulic coupling on the headstock, can now actuate the chucking mechanism. The complete cycle is hydraulically operated and all steps of the cycle are individually adjustable.

HEAT TREATMENT

(82 to 101)

Considerable information has been gathered on heat treatment during the last few years Heat treating equipment may now include convenient means for heating pieces and their continuous handling. Temperature-control devices for this application have been vastly improved. As a result, with data available, the heat treater can assure himself of economical reproducible results

The primary objectives sought in heat treatment are hardness, strength, and toughness Strength is obtained by quenching which, however, introduces the problem of scale Salt baths and lead baths aid in preventing scale, while shot-blasting and nitriding improve surface conditions

Since the usual tempering range is between 200 deg F and 1200 deg F, it has been discovered that two classes of work can be produced within this range For articles subject mainly to wear, such as ball bearings, gears and cutting tools, the tempering range is between 300 deg F and 400 deg F, while objects subject to stresses, such as steering knuckles, are tempered above 800 deg F The zone of 400 deg. F to 700 deg F is now being avoided because of the notch-bar brittleness found there

A relatively new type of tempering has been developed called the bainite structure method which gives a combination of toughness and hardness It consists of heating as usual, then cooling to a temperature of approximately 650 deg F, at which point temperature it is held for a considerable length of time (15-45 min). This treatment yields a particularly tough product with a combined hardness of 50 Rockwell C

INSPECTION

(102 to 121)

There is ample evidence that all plants will depend much more on precise and thorough inspection of all manufactured parts. Formerly, only a few basic types of gages and other inspection tools were commonly used At present, quality control has reached such a state of development that there are over 150 companies engaged in the manufacture of various types of gaging equipment Many new principles, as well as old, are being used in the manufacture of new gages These include air, fluids, light waves, electrons and electricity, all of which make the gaging operation simpler, faster and and the third to be repaired, or if beyond repairing eliminate the human element

The use of amplifying gages is probably the most important step forward in the science of gaging It was difficult for a human mind to grasp any divisions smaller than "tenths," but with amplification of any desired order available, the "tenths" became scale divisions of anywhere up to two inches and the conception of one ten-thousandth of an inch became less awesome

Another factor which has contributed to the improvement of the gaging system is the change in attitude towards gages by the designers Formerly a gage was used continuously and far beyond its useful life No effort was made to check the effect of constant use until errors resulted The modern system requires the employment of three gages for each operation, one on the machine, the second in the tool room for instant replacement of the working gage when it fails to pass daily inspection, scrapped or rebuilt for other operations

On centerless grinding with the newer cycles, the operator places the work on the work blade, the rapid feed advances the wheel to the grinding position and infeed begins After an adjustable spark-out period, the wheel retracts and an air-presure ejector operates If desired, the machine can be converted to complete hand

Electric automatic controls permit precision work without need for highly skilled operator. Push button rapid power traverse unlocks, retracts, returns and locks table in selected position.

Planer table safety stop consists of cutting tools bolted to each end of the bed. Should table run off the bull gear, tools cut into a stop block bolted to the under side of the table.

operation and hand feeding The machine may also be equipped with an automatic hopper feed This is of the vibration type where the parts are fed into a tube and then transferred to the infeed mechanism

The field of centerless thread grinding has lately received a great deal of attention from production engineers Usually, the first question that arises is one of cost The figures are not very well established to date, but the following conclusions come from reliable sources Crush dressing will usually require about five minutes for truing the wheel When running a typical 5/16 in-18 screw, one dressing will be required for each 20,000 screws Production reaches about 2400 pieces per hour with threads meeting Class 3 standards A new straight crusher may be used about eight times before it needs regrinding Tapered crushers for forming throats have three to four times longer life

Of particular interest to bearing manufacturers are the newly developed raceway grinders These machines are now available with complete cycling, automatic resetting of the grinding wheel, optional cycles, sizing devices, easily adjustable angle and position of oscillation, and centralized control stations

One of the more recent grinders grinds the main bearings and fan fit for crankshafts This machine has nine wheels of 42 in-diameter, which grind the seven main bearings, the fan fit and the gear fit An hydraulically operated lateral locator is used to position the shaft and correct for inaccuracy of centerholes An hydraulic wheel dresser is built into the base Each wheel is dressed to its proper diameter in relation to the other wheels from a control station at the front of the machine.

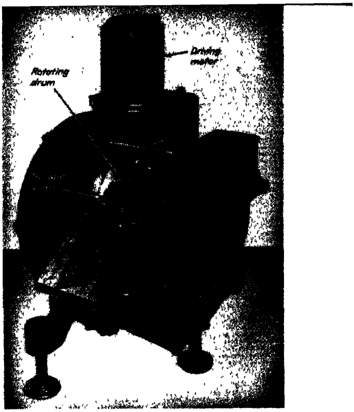
Rapid strides in amplifying gages do not eliminate the fixed snap, plug or ring gages Many changes have taken place in these types, particularly in the use of harder wearing surfaces, such as carbides and sapphire for plug gages These new materials increase the life of gages from ten to thirty times or more, but are not always necessary for gages used on short runs

Dial indicators have been used for a great many years and it is probable that they will always have a place in the modern shop They are now built integrally with plug gages, ring gages and snap gages The addition of this device certainly increases the flexibility of the tool since the exact amount of the over or undersize can be read, as well as the variation from the specified limits

The use of multiple gaging has expanded recently Here a number of dial indicators are mounted on the same fixture. The part is merely located between the various dials by simple blocks A glance at the various dials will then give a complete picture of the suitability of the part for the use for which it is intended.

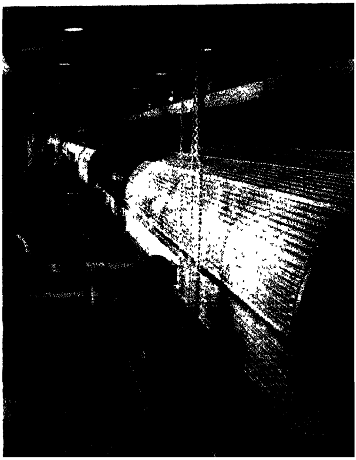
Air gages are finding broader application They are most suitable for round parts, either short or deep, and can be used in a part while it is still located in the machine and without stopping the machine.

Optical methods of inspection are illustrated by the contour comparator whereby an enlarged image of the part is projected on a screen. The screen contains a magnified drawing of the part, and comparison of the shadow image with the drawing quickly indicates any differences that may exist.



An automatic magnetic separator in which radial magnetic fields remove the swarf and abrasive particles from honer and grinder coolants. Cleaning is 95 to 98 per cent effective.

A stainless steel railway car being fabricated by spot-welding process. Spot-welder transformers, thyratron controls, and weld recorders are used in the operation.



To transfer a drawing to a firm surface, Kodak places a translucent drawing over a Transfax-sprayed sheet, exposing the whole to strong arc or mercury vapor lights.

The transferred layout, dried and overcoated with primer, withstands bending and shearing. It also resists torch cutting so that the process may be used with steel.

The optical flats have contributed considerably to the accuracy of modern measuring systems They are particularly useful in measuring flatness and parallelism A skilled operator can read a flat to a few millionths of an inch without difficulty because the measurements are made by the appearance of light interference bands which appear as hills and valleys on the part being gaged Sealing faces of compressors and similar work are checked with optical flats

Multiple inspection gages have been developed to check as many as twenty dimensions at the same time without any particular operator skill being required This fixture has been developed for gaging aircraft cylinders and is so arranged that a colored light will flash only when the specific dimension it controls is outside the tolerance limits

Surface inspection is one of the newer developments receiving attention The Profilometer consists of a fine stylus which, when moved across the surface, gives an amplified reading of the depth of surface markings A series of master finish blocks is furnished with the machine as a basis for comparison Optical comparators and microscopes are also being used for this purpose

It is predicted that manufacturing economics will be greatly affected by developments in inspection Scrap losses will be held down to less than 5 per cent instead of the 20 per cent to 50 per cent now being found in some industries A better product, produced more cheaply, will result

LATHES

(122 to 141)

Modern lathes are now broadly classified as all-purpose or special purpose machines

The all-purpose machine is undergoing changes in construction rather than in the possible uses for which it has been designed A newly designed lathe is now equipped with double carriages, front and rear, each independently actuated by its own feed screw This lathe is designed for the use of multiple tools in turning, boring, straight and angular facing operations Work can be mounted on an arbor, or held in chucks and fixtures All feeds can be controlled, giving rapid forward and return traverse, a timed dwell and an adjustable length of power traverse.

Wide-face, alloy steel headstock gears have shaved and hardened tooth profiles. The front of the spindle is mounted on a double row of tapered roller bearings Lubrication of the headstock is entirely automatic by a pump from the reservoir.

For the feed and traverse mechanisms, two control boxes are furnished, one at the front and one at the rear of the lathe. These boxes house mechanisms for operating and cycling the tool slides and carriages by the rotation and stop of feed screws. Length of feed cut is determined by the setting of the stop nuts on the trip screw at the carriages.

During the forward movement of the trip screw, a multiple disk clutch is brought into engagement, supplementing the position of the feed drive. With the positive clutch fully disengaged, the feed screw is pulled up solidly against the control box. At this point the disk clutch slips, and the feed screw has been brought to rest by the trip screw being pressed against the solid stop of the control box.

At the head of the apron an adjustable micrometer sleeve is used as a diameter stop When the traveler nut comes in contact with this sleeve, the block is no longer free to move inside the apron The block, therefore, automatically moves the carriage toward the headstock until the block contacts the nuts on the trip screw In angular feed, the infeed motion of the tool slide is simultaneous with the longitudinal movement of the carriage Stop nuts limit this travel

In order to reduce noise and its attendant vibration, the use of herringbone gears in the headstock is becoming more prevalent More power can be transmitted and smoother work results because tooth chatter is practically eliminated Such results are obtained by means of the overlapping tooth contact in this type of gear

Special purpose machines, such as crankshaft lathes, duplicating lathes and centering lathes, have made great strides in their production capacities

Improvements in *crankshaft lathes* have produced greater accuracy and higher production They are now being built for rough or finish turning of all pin bearings, and rough and finish turning of all line bearings with tolerances that were hitherto thought to be impossible Super finishing has been undertaken by some manufacturers, a field that holds particular promise in diesel manufacture

The *duplicating lathe* is a combination of a standard lathe together with an inbuilt hydraulic duplicator The lathe will produce, from a template mounted on the rear of the lathe, any shaft having an irregular contour The tool slide operates at an angle of 45 deg to the work axis, which compensates for the longitudinal movement of the carriage and permits the production of square shoulders as well as the execution of radii and bevels

The *automatic lathe* has been designed for the production of valve guides and similar parts These are automatically turned in double-end drive machines The drive for both spindles is by pulleys and V-velts from a splined jack-shaft Parts may be rough and finished turned in the same operation with separate tools Automatic feeding consists of a chute down which the parts are fed directly to the chucking mechanism

The *shaft centering and facing lathe* comes in various sizes to suit the shafts being machined One standard range is from 1¼ in to 6 in diameter and lengths from 9 to 49 in The machine operates on a fully automatic cycle with pushbutton controls and can average 500 shafts per hour doing both the centering and facing operations

The *turret lathe*, which holds a position somewhere between the all-purpose lathe and the single purpose lathe, has recently been equipped with an electro-pneumatic control Dogs on a rotating drum actuate levers that trip solenoid switches to adjust speeds and feeds Four automatic changes of spindle speeds may be obtained with each set of hand pick-off gears

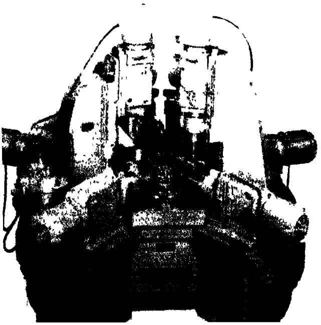
Three automatic changes of feed are also secured with each set of gears The multiple disc clutches are pneumatically engaged so that linkage failures are not not possible The change from rapid traverse to reverse speed is accomplished in 1/5 second The cross slides of the machine can be arranged for either independent or simultaneous motion

MILLING

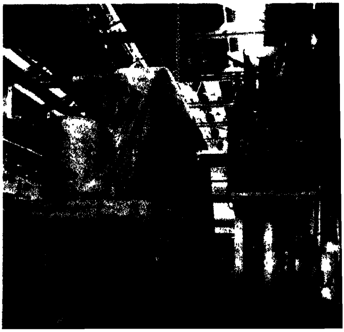
(142 to 167)

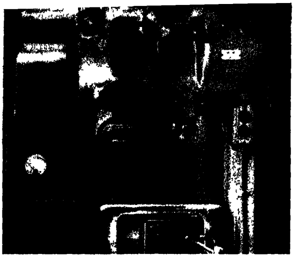
In order to obtain the full advantages of tungsten-carbide cutting tools, one of the latest improvements on milling machines is a heavy flywheel mounted inside the column of the machine This addition permits smoother operation at higher spindle speeds

Turret-type Fleximatic has 24 spindles and performs successive operations with a single chucking. Automatic indexing permits finishing 530 valve bodies per hour.



Massive table-type, open-side mill shown boring and facing tie rod holes on a 144,000-lb press bed. Dimensions are 10 by 10 by 30 ft.





Loadmeter is mounted on the side of the column of a horizontal milling machine. Meter shows operator whether he is using machine to its full capacity.

The installation of a *load meter* has proven a valuable adjunct in determining the power capacity of the machine It consists of an ammeter in series with the wiring for the spindle motor, and reads in a per cent of the full load The meter enables the operator to determine whether he is making full use of his machine Dull cutters can also be detected by noting load increases, an important factor in the use of carbide cutting

The centralizing of controls has always engrossed milling machine designers One of the latest designs of milling machines has a bank of control buttons mounted adjacent to the operator's position This consists of 13 controls with the following functions rapid traverse control that unlocks the table, retracts, returns, and locks the table in a selected position Vertical feed and bar feed are similarly controlled An emergency button can be operated to stop any machine function instantaneously End measure gages are used for automatic positioning One button causes the slide to move in rapid traverse at an approach location and then complete its positioning within 0 0001 inch of the position of the end measuring gage At the point of final location, the tension in the lead screw is released; and controlled pressure locks secure the head to the slides

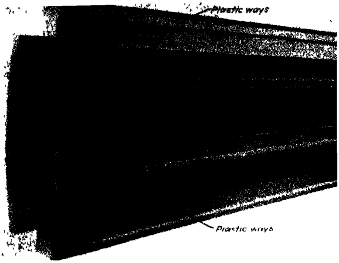
The *duplicating milling machine* has been receiving wider acceptance among machine builders. One machine automatically duplicates dies from a master die or pattern, thus relieving the operator of considerable work and responsibility Time is saved in roughing out the die impression because heavy cuts can be taken, saving time in hand finishing due to the accuracy of the machine-cut die impression These machines are completely hydraulic in drive and feeding operations.

PLANING

(168 to 171)

As in other machine tools, the planer has made rapid strides in the direction of higher production rates. The advent of the cemented carbide cutting tool has necessitated more rugged design throughout, higher cutting speeds and feeds and better control of generated heat.

The application of variable voltage drive to planers has increased the ranges of speeds to 300 fpm with a large number of variations in return speeds all instantly adjusted by the simple operation of rheostats. A table drive ratio of 4 1 is usually employed with motor speeds of 40 to 1200 rpm The lower available speeds with this setup permit the planing of alloy steels without exceeding the economical life of the cutting tools



Planer design has been improved through the use of laminated plastic ways which prevent heat transfer from the bearing surfaces to the table.

One of the latest improvements in planer design is the use of *laminated plastic ways* held in place by laminated plastic pins Several advantages result from this type of construction The first is heat dissipation Due to the low co-efficient of heat transfer, the plastic ways prevent the heat generated in bearing surfaces from being transmitted to the table and subsequently warping both the table and the work located upon it The new ways also have a lower co-efficient of friction, thereby saving power Their load-carrying capacity is about 50 lb per sq in at 400 fpm, instead of a maximum of 20 lb per sq in with metal ways Damage to the ways is further reduced, because chips will not embed themselves, thus preventing the scoring usually seen on the older types of planers

Better lubrication contributes to improvement in the design of planers An inbuilt pump continuously supplies filtered oil to all wearing parts

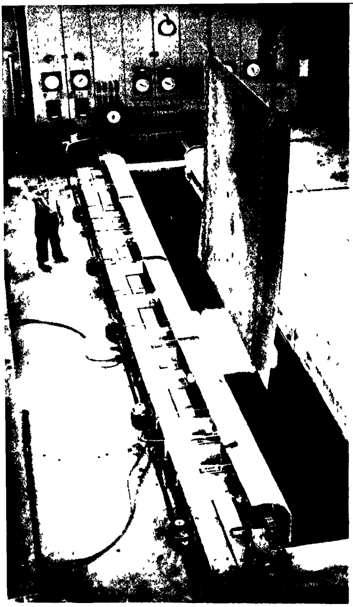
Hypoid gears are now used for the main reduction drive The pinion is straddle mounted and the helix angle so arranged that the thrust produced is practically balanced out The pressure angle of the bull gear is held to a very low figure (9 deg in some cases) in order that the upward thrust of the gear can not become equal to the weight of the table itself.

Several solutions of the table over-run problem have been worked out by the various planer manufacturers. In one of these, a cutting tool is mounted on the bed itself and a block of softer steel is bolted to the planer table If the table should overrun the bull wheel because of failure of the limit stops, the energy of the moving table is absorbed by the cutting tool cutting into the block This gives unfailing protection even though it may never be used during the life of the machine A rack is attached to the table in such a way that the pitch of the rack is fixed to the bull gear so that the table can be moved back on the bull gears without damage to its teeth.

STAMPING

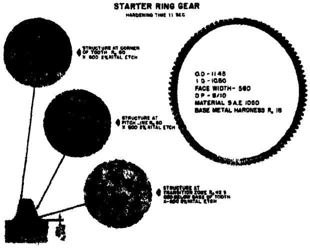
(172 to 180)

The present tendency is toward faster press speeds



World's largest salt bath furnace removes scale from hot-rolled clad plate and sheet for the Lukens Steel Co. Economical advantages over acid pickling have been demonstrated as well as absence of pitting or hydrogen embrittlement.

Flame hardening holds parts to dimensional tolerances and metallurgical specifications. Pictorial analysis shows a part which has been treated by a hardening machine, employing temperature control and oil quench.


STARTER RING GEAR
HARDENING TIME 11 SEC
STRUCTURE AT CORNER OF TOOTH R. 60 X 600 2% NITAL ETCH
STRUCTURE AT PITCH LINE R. 60 X 600 2% NITAL ETCH
STRUCTURE AT TRANSITION ZONE R. 42 3 .050 BELOW BASE OF TOOTH X-600 2% NITAL ETCH
O.D - 11.48
I D - 10.60
FACE WIDTH - .560
D P - 8/10
MATERIAL S.A.E 1050
BASE METAL HARDNESS R. 18

Balls are examined at the Swedish SKF Ball-bearing Company's plant at Gothenburg. They are automatically fed into holes in a rotary plate and pass slowly before the inspector.

than heretofore used. The mechanical press has until recently held an advantage over the hydraulic press in speeds of ram advance, pressing, and ram return. However hydraulic press manufacturers have somewhat overcome this advantage by the use of fast-acting valves and motors. Hydraulic presses are available with opening and closing speeds of 1300 in. per minute and pressing speeds of 335 ipm.

A new development in press tools is the use of soft and easily shaped materials for dies such as zinc alloys, lead, wood, masonite, plaster, plastics and combinations of these materials. As a further step it is now possible to cast tool steel to approximate final shaps so that a minimum amount of machining is required.

Stretching, while not a new process, is being used more frequently due to soft, easily constructed dies. The process is eminently suited to the production of aircraft skin sections where large or small quantities of parts are required. It is now used for some automobile work.

Considerable development has taken place in the deep drawing of steel. Several methods are available for coating steel sheets thinly with copper to act as a lubricant and to prevent the sheets from tearing. With this newly acquired knowledge, it is now possible to produce many parts from steel formerly made of copper, brass and aluminum. Likewise, steel products that once were made in two parts and then welded or brazed, can now be deep drawn in one piece without seams.

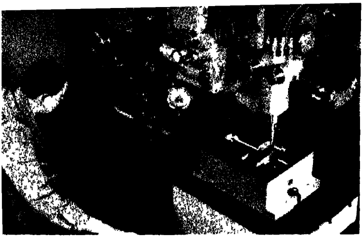
On large presses, it is possible to produce a dozen or more parts of assorted shapes and sizes, all at the same time. This is due to the development of the Guerin process wherein the pressure portion of the die consists of a heavy rubber pad. Under pressure, the rubber blanket flows around the dies on the bed of the press and forces the metal to assume the desired shape. Rotating index fixtures are used in this work to increase productivity further.

WELDING

(181 to 188)

Since 1946, resistance welding increased because of the development of the battery operated welder. The flash welder for aluminum has also become prominent.

Arc welding has been aided by the discovery of lime-ferritic electrodes for high sulphur steels, air hardening steels and alloy steels. Welding wires are also undergo-



Milling machine, with automatic depth control unit at right, cuts crankshaft according to master.

ing several changes because of a tendency among manufacturers to use smaller wire with increased welding current

The carbon arc torch is finding considerable success, particularly in rural communities Its high concentrated heat and ease of control make it valuable for handling many complicated jobs

In the related field of atomic-hydrogen arc welding, a three-head torch has been developed that permits faster work and better control of the cooling temperatures

In the field of inert gas that involves shielded arc welding using either argon or helium, developments have extended the application of this type of welding to metals other than magnesium and aluminum The elimination of fluxes has definitely created a place for the inert gas shielded arc welding system.

Several developments have taken place in the use of the oxy-acetylene flame torch

By using a hollow metal electrode with an oxygen stream it is possible to cut non-ferrous metals This method is also used for applying hard facing to thin edges, without distortion When finely divided hard-facing materials are introduced into the welding gases, the need for both rod and flux is eliminated. Since stainless steels are becoming increasingly important in industrial production and fabrication, methods of flame cutting these materials have been developed. A powered metallic is introduced into the oxygen cutting stream so that the oxy-acetylene reaction will provide the necessary heating, melting, and fluxing to remove the refractory chromium oxide.

Pressure welding is a newer development for making butt welds The two faces to be welded are cleaned and then forced together under pressure while being heated by a number of oxy-acetylene flames The material becomes plastic upon attaining the welding temperature and is fused by the pressure The joint is as strong and ductile as the base material, since no outside material is added to the joint

Gas welding, in common with other methods of fusion, lends itself to mechanization The torches may be motor driven on a track along the seam with or without the addition of filler rod, as conditions may require Template control of the cutting torch has solved several problems in machine production, particularly where production is limited to a few pieces An example of this was the flame cutting of a crankshaft for a diesel engine from plate 32 in thick In this case, the slab was preheated to reduce cutting time

Illustrations for this chapter were obtained through the courtesy of the Lodge and Shipley Co, Fellows Gear Shaper Co, Van Keuren Co, W F. & John Barnes, Gisholt Machine Co, Cincinnati Bickford Tool Co, Canadian Anodized Products Ltd, Canada Pictures (Toronto), Westinghouse Electric and Manufacturing Co, Gallmeyer & Livingston Co, University Machine Co, Bryant Chucking Grinder Co, G A Gray Co, DeVlieg Machine Co, Barnes Drill Co, General Electric, Kingsbury Machine Tool Co, E W Bliss Co, Van Norman Co, Ajax Electric Co, Cincinnati Milling Machine Co, American Swedish News Exchange

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CHAPTER XVII

MINING

by A. H. HUBBELL

Rising costs and falling ore-grades have stimulated the metal and non-metallic divisions of the mining industry to improve their technological practice New levels of efficiency have been attained in open-cut mining and underground operation alike The industry, long regarded as well equipped for production, has become more highly mechanized New materials and machines, also new ideas and new applications of older ideas, have been used to advantage

Rock drilling, loading, haulage and transport, both underground and on surface, exhibit the greatest progress The job of breaking the ore and delivering it to the point where it can be shipped or treated has been eased and cheapened Other operations also show improvement Mucking the broken ground in putting down a shaft was long the hardest work in sinking It may now be done mechanically Hoisting and hoists, including the wire rope, have undergone improvement Ventilation is treated seriously by mine owners, and air-conditioning is forging ahead To a greater extent than ever before, knowledge and experience developed in other branches of engineering and industry are being utilized

A spur to progress has been the bad labor situation Despite high wage scales, the supply of skilled labor, especially of miners, is still insufficient in many places. Absenteeism and "loafing on the job" also have tended to keep output down and costs up. Labor-saving equipment is therefore popular with management Slow deliveries still hinder such improvement.

Drilling

For breaking rock and ore underground, the air-driven rock drill has no competitor except under special conditions. Where the material mined is soft, as in the case of potash and salt, the electric-driven auger drill may profitably take its place (1). Where the ground-breaking method permits the drilling of many holes from one set-up (by swinging the drill in a given plane), or allows a row of long holes to be drilled from a bench by shifting the set-up a few feet each time, the diamond drill may offer advantages in a lower cost per ton broken and in greater safety (2). However, conditions cited are exceptional. The rock drill is breaking a very high percentage of the total tonnage of ore mined today.

The modern power-feed drifter is typical of the newer drills. Of moderate weight, with low air consumption, high drilling speed, long life and low maintenance, it is easier to handle and run and should give bigger footage and tonnage per shift. The power feed also speeds up the work of backing out of the hole.

Jumbo Speeds Setting-Up

Much has been done to lessen the time required for setting up a drill in drift or stope Mountings for individual drills have been improved Air-column bars are available Stopers can be had with air-feed legs Where more than one machine is used at the face, the modern jumbo, carrying its drills already mounted and connected to air and water, will prove a time saver. To illustrate, in one mine four drifters on a jumbo were set up in six minutes, as against 20 minutes for setting up a single column-mounted drill in another drift

While not new in tunnel work, the jumbo in the last few years has found wide favor for drifting and even for drilling in stopes Recently, it has appeared in various models Among the unusual types are the following

A one-man single drill jumbo having a pneumatic column, the whole being mounted on a two wheel truck with two handles for pushing

A folding, skid-mounted, single-drill jumbo for use in trackless drifts between levels.

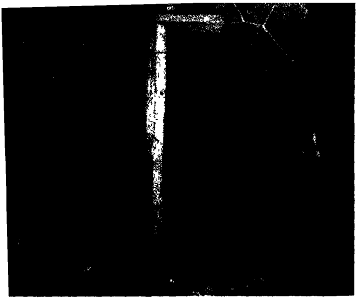
A two-drill hydraulic-jib jumbo mounted on a self-propelled low truck having four rubber tired wheels The drills have especially long feeds

A two drill track-mounted jumbo having a gear rack on each column with a crank for raising the cross arms

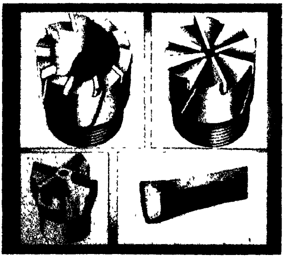
A 3-drill crawler-mounted jumbo (1) for stope use, each drifter being mounted on wagon-drill sashes and moved by *chains, sprockets and air motors (3) Two men operate the* three drills

A 5-drill jumbo (4), having five power-feed drifters mounted on a high platform which is supported and carried by a tractor (4) With it five parallel uppers can be drilled at a time in the back of the large open stopes for which it was developed

A shaped charge placed against the underside of a large fragment of ore blocking a chute.

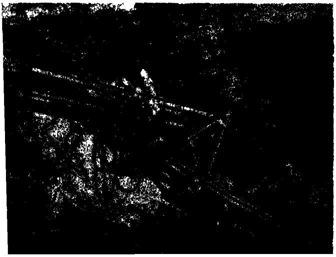


Detonating fuse is used underground as well as in surface blast holes. Here the holes of a single ring, drilled with diamond drills, are tied together with Primacord, ready for simultaneous detonation.



Drill bits set with tungsten-carbide inserts on the cutting edges. (1) Bit end of Swedish jumper drill, 4½ ft. long, such as has been used on the Rand. (2) A recently introduced 4-point detachable percussion-type bit. (3) Rotary bit, coring type. (4) Rotary bit, non-coring type.

Three-drill jumbo, crawler-mounted, used in zinc mine. Two men run the three machines. 10-ft. steel is used.



In short, the jumbo has found a well-defined place in underground drilling.

Detachable bits of the types that have become standard over the past 15 years are accounting for the larger part of the total mine production (5). Although considerable sharpened steel is still employed, three-quarters of United States mines and quarries are using bits. In Canada, bits are reported to account for 90 per cent of the Dominion output The domestic field is largely supplied by Ingersoll-Rand and Timken, the former now having a stud-type (two-piece) bit in addition to the regular one-piece Jackbit In Canada, the Craig throwaway bit and the Hayes bit, which is used several times, dominate that field Other bits in the Dominion are the Liddicoat and Redington (6) The former is now being used also by Calumet & Hecla in the United States In South Africa two bits have been popular, the P. & M. (throwaway) and the Simplon (re-use) (7).

What counts with the user of detachable bits, whether of the throwaway (one use) or the re-use type, is the cost per bit-use and the cost per foot of hole drilled. The number of usages obtained per bit varies widely with the user One is said to get 14 such usages The average is 5 to 6.

Of the bits named, the stud-type is the newest (5) It consists of a factory-made stud of alloy steel which has a reverse buttress thread on the bit end and a machined, undulating, conical surface on the other. The latter end is driven into the rod by a drill-steel sharpener Redesigned Jackbits in several stud sizes are being made for use with the stud The stud permits heavier construction in small-bit sizes, so that the bit has a thick body to take the drill blows transmitted through it The stud may be bought with its thread accurately made in the factory instead of being fashioned in the mine shop where the treatment of alloy steel may not be understood Alloy-steel rods may be used with the stud (8).

Smaller Bit, Smaller Hole, Faster Drilling

Attention is being given the idea of drilling a round with a hole of smaller diameter, thus decreasing the amount of rock to be cut and in turn getting more drilling speed for the same power The hole must be large enough to take sufficient powder to break properly By starting at 1⅞-in diameter instead of 2½-in. and using 1/16-in. gage changes instead of ⅛-in., it would be possible to finish at a size large enough to permit this. The practice would also permit use of lighter-weight machines taking less air and costing less to maintain.

Practice in Canada has been trending toward use of ⅞-in. steel instead of 1-in quarter-octagon. Approximately 40 per cent of a large group of mines surveyed in eastern Canada are using the smaller size, in an alloy steel. The rest prefer the larger hole with straight carbon steel.

Experimenting with holes of a diameter larger than usual is also being done. For shooting them, powder has been made in experimental lots in sticks 2 in. in diameter and 16 in. long. The idea is to drill a round with fewer holes. Thus time and labor could be saved in drilling and loading.

Drilling With Diamonds

Fifty mining companies, more or less, are known to be using diamond drills for drilling blast holes for ore production (2). More than half of them are in Canada where the extensive employment of this practice began approximately 10 years or more ago.* Most of the others are in the United States, a few being scattered abroad. The portion of each company's tonnage produced by diamond drilling varies greatly, from less than 10 per cent up to almost 100 per cent.

The diamond-supply situation and the advance in prices of industrial stones, which took place in 1946, seems to have had little effect on the blast-hole footage drilled by the industry (5). A prominent drilling firm anticipates increased rather than decreased use. The increase in cost per foot drilled, which would result from higher prices for stones, is secondary to the cost per ton of ore broken. With the mining method commonly used with diamond drilling, the latter cost is much reduced.

Significant results obtained in blast-hole diamond drilling are given.

Average footage drilled per machine shift for 27 users ranges from 31.6 to 150. In 20 of the 37 cases it is over 40. In five cases it exceeds 85.

Average tonnage broken per foot of hole drilled for the same users ranges from 1.5 to 6.5. In all except five of the cases it is 3 or more.

Cost per foot of hole for the 27 users ranges from 0.27¢ to $1.12 (U. S. cy.). In 10 cases it exceeded 0.50¢. These costs are one year old at the time of this writing and include at least several months in which the higher prices for stones were effective.

Experiments made with holes 1 15/16-in. in diameter have determined that, with the powder concentration of 1.6 lb. per ft. of hole permitted by this large design, 8 tons or more was broken per ft. of hole under good conditions.

Tungsten-Carbide Bits

The rock-drilling situation being otherwise as described with respect to bits, it recently has been vested with doubt as to the future by the introduction of both percussion-type and rotary bits having inserts, on the cutting edges, of tungsten carbide or so-called "hard metal" (9). So remarkable have been the drilling speeds obtained with this material and the length of bit life exhibited, particularly when used with the ordinary rock drill, that the art of drilling rock appears to be about to take a great step forward.

"Hard metal," consisting of cemented carbides or tungsten carbide plus certain alloying metals, has been known for two decades. Under the trade name "Widia" it was used in Germany after World War I in wire-drawing dies. Some years later it was tried successfully for drilling rock. Five years ago, the Sandvik Steel Works in Sweden undertook to test it. The result was their Coromant jumper drill which has a slab of tungsten carbide brazed into a slot cut along its chisel edge. Three companies in Sweden are now making such drills.

Imported into South Africa, this jumper has done excellent work on the Rand, where it has been used in a light jackhammer. The cost of such drilling is still in doubt. Reporting for Van Dyk Consolidated Mines, the engineers stated, among their conclusions, that "for normal stope drilling the present cost of tungsten-carbide jumpers (said to have been £3 10s.) is still much too high to warrant serious consideration of a change from normal steel (9).

Development of tungsten-carbide bits in the United States was delayed until after the war by pressure of war work. Remarkable progress has since been made. Already several lines of bits have appeared. These include the Carset Jackbit, a four-point (or cross) bit made by Ingersoll Rand Co. in collaboration with Carboloy Co., the two-point chisel-edge Carr-type bit and various rotary bits made by Kennametal, Inc., and the line of bits only recently announced by Firth-Stirling Steel & Carbide Corporation.

Experience with bits of the first two makes has been recounted in recent articles (9). Let it suffice to say here that the experience is varied. In some ground, carbide bits drill marvelously, giving many times the footage obtained with ordinary detachable bits and with a bit life of perhaps several hundred feet. In other ground, a bit may fail miserably, the inserts breaking or pulling out. Obviously, considerable trial work remains to be done. Despite the difficulties, the future for tungsten-carbide rock drilling appears promising.

The Shaped Charge

Blasting is as essential to breaking ground as the drilling that must precede it. Disappointingly, this summary cannot include, with respect to explosives, accounts of developments such as have signalized drilling progress. There have been very few developments in recent years, according to the explosive makers. For a time a possible sensation loomed in the shaped charge, which utilizes the so-called Monroe effect, whereby a considerable portion of the energy can be directed along a given line with amazing effect (10). This is obtained by fashioning a conical cavity of calculated dimensions in the underside of a charge. It was this jet effect that accounted, in part, for the bazooka's success in piercing tanks and for the destruction caused by demolition charges. Logically, it was reasoned at a western mine after the war that the principle could be used to good effect in connection with mining explosives. Shaped charges were made and used successfully in opening stope raises blocked by large fragments. Prominent explosives manufacturers, however, charge that this is technically wrong. As good, or better, results can be had, they assert, with a properly prepared bomb, or bundle of sticks. At present a western copper mine is doing a secondary blasting in its open pit with shaped charges supplied in three sizes by a prominent maker. An order for 11 tons was recently reported. It would appear that the last word has not yet been said on the matter.

Short-period delays have been introduced for detonating a charge where it is desirable to reduce the

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*** Diamond drilling of blast holes was first used in the Soudan iron mine on the Vermilion Range in northern Minnesota about 50 years ago. It was discontinued because of the then rising cost of stones. The practice was revived in 1937 when Noranda Mines Ltd., in Quebec, substituted diamond drills for the rock drills it was using in drilling long holes with jointed rods, in fan-shaped patterns drilled from a single set-up.**

vibration from the shot and improve the backbreak. They permit various combinations with instantaneous delays. A so-called blasting-timer machine has also been introduced to accomplish the same thing. With it a series of charges can be fired at pre-determined intervals as short as 0.005 of a second.

It may be noted that detonating fuse is being used underground to an increasing extent.

Mechanized Scraping and Loading

Mucking, or removal of the broken rock or ore from the face in the heading or stope, has become highly mechanized. Labor shortage has speeded the mechanization and made it more complete. The need for lowering costs has also helped. Taking the place of the hand-shoveler are the mechanical loader and the scraper.

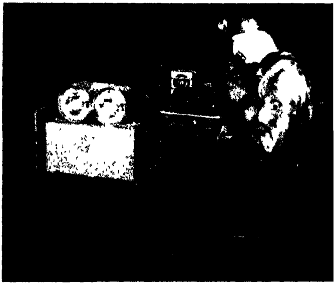
Two general types of loading machine are in commonest use: (a) The dipper type which raises the ore "over its back" and dumps it into the car hooked on behind (11). The Eimco and Gardner-Denver machines are the best known shovels of this type. (b) The conveyor type, both rail- and crawler-mounted, such as the Joy and the Goodman, which "claw" the rock on to the foot of a belt which conveys it up and back into the car behind (1). This type has been used chiefly for non-metallic products, but a loader of Joy make, designed for handling iron ore, has recently been put into trial use with shuttle cars in the Birmingham district.

A recent innovation has been the use of the Eimco shovel for mucking out a winze being sunk at 23 deg. A drum and cable attached to a rear wheel control the mucker's movements on the sloping track. Operation is otherwise the same as on the level.

A growing practice where certain stoping methods are used is to pull out the loading chutes and let the ore run on to the level where it is shoveled up with loaders (12). This saves labor, avoids chute accidents.

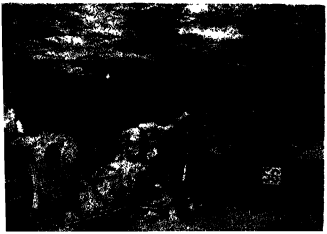
Introduction of crawler-mounted loaders has led to

10-ton diesel locomotive built by a British manufacturer for underground service. Exhaust gases are conditioned by water washing. The unit can negotiate 40 deg. curves on 35-lb. rail when running alone.



Trolley telephone, utilizing overhead wire, provides convenient means of communication between motorman and the dispatcher or shift boss.

Shuttle car (left), at end of its haul, is delivering load (by means of pan conveyor which forms its bottom) to gooseneck conveyor in center and thence to main-line haulage train.



Dipper-type crawler-mounted loader, that can carry as well as dig its load, filling a truck in large open stope in an underground limestone mine. Both truck and loader are diesel-powered.

a diversity of types Typical of one group is the Traxcavator which digs its dipperful, raises it up, travels on crawlers to the truck, dumps its load and returns for another It combines the loading and transport functions

Scrapers come in the hoe type and the box type, the former predominating (13) They may be operated by air hoists up to 35 hp or electric hoists up to 150 hp The electric-hoist motors may be a-c or d-c, both of which have ardent champions Some electric installations are equipped with remote control, manipulated by the operator at a point away from the hoist where he can watch the loading better

Folding Scraper

An outstanding development is a 72 in hoe-type scraper that folds up when pulled back, thereby avoiding the heavy pull on the tail sheave when large rocks are met Open, it is 56 in high, folded 26 in Developed by Climax Molybdenum Co, it has been taken over by the Eimco Corporation

A shaker-conveyor line delivers ore broken by block-caving mining method from stope chute (at far end) to raise in foreground.

Scraping is flexible and permits many variations By use of snatch blocks, the scraper may be operated at angles to the center line of the hoist By setting the hoist above the drift, it may drag alternately from two opposite headings With the hoist on a turntable, slushing (i e, scraping) may be done from any direction

To expedite the handling of trains at the shaft pocket, a train may be dumped into a trench paralleling the track While the train passes on, a scraper drags the ore in the trench to the pocket

In some mines, loading chutes have been removed and the ore from the raises is let run into a drift just over the haulage track (14) A scraper in the drift transfers it to a hole in the floor through which it falls into a car

The scraper slide is yielding to shovels for mucking out headings In portable form, it is used to scrape from various points, delivering to cars on the track

Shaft Mucking

The Riddell shaft mucker is one answer to the problem of shaft mucking (15) It comprises a $\frac{3}{4}$-cu yd. clamshell bucket hung from a carriage that carries three air motors and is movable within a frame attached to the shaft timbers The operator works from the carriage Any point in the shaft bottom can be reached. Another type of mucker recently built under the Boskovich patent uses a power-shovel bucket, suspended beneath a cage and crowded into the muck by an air piston

Haulage and Transport

Time-tested electric haulage, of both the trolley type and the battery type, remains strongly entrenched underground The relative position of the two types is little changed For long hauls and large capacity, trolley haulage is preferred Where already installed, it is likely to stay The typical use for battery locomotives is for gathering on the main (trolley) haulage level and for hauling only on those levels where there is too little work and too short hauls to justify the trolley type

Advantages of battery haulage are that the locomotive is flexible up to its full ampere-hour capacity, and the system is safer for everybody because it requires no live wire overhead More powerful batteries now permit the small trammer-type locomotive to be used for the entire shift without recharging A 36-cell battery, good for $14\frac{1}{2}$ kwh, can be had, compared with the 40-cell battery with a capacity of $9\frac{1}{2}$ kwh formerly supplied.

Competition From Diesels

Diesel locomotives, once taboo underground because of unpleasant exhaust gases, can be used where ventilation is good (16). The exhaust gases must be conditioned first This position is maintained by the United States Bureau of Mines. Backing it up is the fairly extensive use of diesel locomotives in some European countries and in South America. Installations of diesel engines underground cited by the aforesaid Bureau include

(a) Eimco loader in a mine in the Tri State District (b) Trucks in a Virginia gypsum mine (c) A 3 ton locomotive in a California tungsten mine (d) Diesel and gasoline powered equipment in a dam tunnel in Pennsylvania (e) A loader in the Bureau's oil-shale mine in Colorado (f) To these may be added the locomotive in the Treasury tunnel in Colorado

Unpleasant odors from the exhaust unquestionably provide a serious obstacle Nevertheless, the economy and low-maintenance cost gained in diesel operation are not to be ignored One operator points out that an adequate air filter is necessary if the mine air is dusty

Making Haulage Safer

With small locomotives, accidents can be caused when some one, walking alongside, moves the controller To prevent this, Atlas Car & Mfg Co has provided an interlock which prevents the motor from being moved save when the motorman is seated with his foot on a safety switch

Another practice to make haulage safer includes the use of an improved trolley guard of flexible, flame- and acid-resistant material, capable of withstanding high voltage It protects the pole as well as men from the wire Another item is the use of an electric eye to sound a warning signal at a junction to announce the approach of a main-line train, also to open and close ventilation doors in the haulage way Where traffic is heavy in large mines, some sort of block-signal system is imperative

A new feature of modern haulage, that incidentally has a safety angle, is the trolley telephone, whereby communication may be had by the motorman with the foreman, dispatcher or other person The overhead wire is employed (43).

Trackless Mining

Borrowed from coal mining, the rubber-tired shuttle car has proved its value for transport in underground mines producing salt (17), potash (1), gypsum (18) and bauxite (19) Loading is done by crawler-mounted conveyor-type loaders Modified in design and construction for handling heavy metallic ores, it has recently been introduced by the Joy company in a Birmingham iron mine, where it will be loaded in like manner Another installation, to be loaded at the outset by scraper, is on order for a non-ferrous metal mine also in the southeast

Shuttle cars travel at 3½ to 4 mph loaded and 4 to 5 mph empty (20) Capacities range from 4 to 10 tons The crawler-mounted loaders load 2 to 8 tons per minute Advantages of the combination are elimination of track work and track haulage in the working place and reduction of it elsewhere This holds loader time losses to the minimum by spotting the shuttle car hopper right under the discharge boom of the loader, together with the ability to load waste rock in the shuttle car for removal Maintenance costs (1946) were 0.03¢ to 0.05¢ (U. S cy) to 5¢ per ton.

Side-Dumping Mine Car

A survey of underground mine cars used by 33 major companies (21) shows that a side-dumping type is preferred, the Granby type leading the rocker and gable-bottom types Other types favored were the end-dump, bottom-dump, and rigid-box type requiring rotary dumping Capacities vary from 1 to 12 tons Practically all cars have anti-friction bearings An outboard spring mounting provided in one company's Granby-type cars makes them clear themselves better when dumping

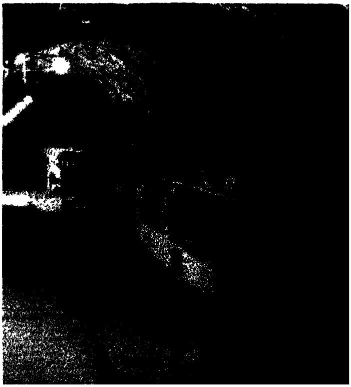
Conveyors Useful Underground

Belt and shaker conveyors are slowly making their way in the field of underground transport (22) The successful use of belts in open cut work has had a favorable influence Improved construction of belting using steel and cotton cords lengthwise and various materials in the fabric, permits greater length of conveyors between pulley centers The newest development of the U S Rubber Co, said to be 2½ to 4 times stronger than any other belting will trough perfectly, according to the company In its first utilization (in a coal mine), the conveyor will be 2600 ft betwen pulley centers, rising 630 ft at 15 deg

Outstanding underground installations include the shaker-fed belt-conveyor system which transfers the iron ore from top-slice stopes to the shaft pocket in the Sherwood mine, northern Michigan (23) This comprises two belt conveyors all on one level (total rise 6¼ ft), one 818 ft center to center, and the other 648 ft Capacity is 200 tons per hour

In contrast, the 2496 ft-long belt system in the Kimberly mine, British Columbia, lifts the ore 680 ft vertically in going from the 3900 to the 3400 level, has a capacity of 400 tons per hour (24) It saved sinking a new shaft

Conveyor line carrying iron ore to shaft pocket on one level. The belt receives its load from shaker conveyors that come out of the stopes, or working places.



The Shaker Conveyor

Adoption of shaker conveyors outside the coal industry has proceeded slowly (25) The Iron Country now boasts installations in five mines compared with two mines 18 months ago Two copper mines in Arizona have used them for six or seven years in connection with block caving Shakers are suitable for handling coarse or fine, preferably dry, materials over moderate distances.

Over a period of three years Kennecott Copper Corp , at its Ray Mines in Arizona, obtained an operating and maintenance cost of 0 075¢ per ton Items entering it were. pans and liners, 0 075¢, installation and operation, 0218¢, maintenance, 0 427¢ and power, 0030¢ Future cost, it is estimated, will not exceed 065¢ (U S cy) per ton

An installation in Mexico gave an operating cost for a 328 ft haul of 0 035¢ per ton, against 0 067¢ (U S cy) for a battery locomotive and 40 cu yd side-dump cars

Hoisting Practice

Substantial progress is being made in hoisting practice Attention is being given by designers to such matters as the following·

Reduction of fleet angle to reduce rope wear, provision of greater sped to increase shaft capacity, design for compactness where space is cramped, and the use of multiple-tooth clutches for greater safety Also to reduce rope war, winding in a single layer on the drum is favored

Hoist control of the Rototrol or Amplidyne type is becoming the regular thing, insures proper hoist operation despite possible carelessness on the hoistman's part, and prevents excessive speed, burned-out motors, overtravel and unnecessary use of power (26) The possibilities of full-automatic control, such as that exemplified in the Inspiration hoist in Arizona, are also being studied

Up-to-date means of communication between hoistman and cage tender have been provided in one of the Homestake shafts to permit giving insrtuctions while the cage is moving Here the hoisting rope is used to carry a fundamental frequency which can be modulated for voice transmission

Wright-Hargreaves' development of rubber-tired skip guide-wheels, to prevent wear of wooden guides, is being copied (27)

A push-button automatic elevator has been installed in the Boyd shaft at Ducktown and in the Mather headframe at Ishpeming In each case a hoistman is unnecessary and work is cased for the workmen

Light-metal alloys are being utilized to cut cage weight and boost live load, as in the aluminum cage.

Mechanical loader of dipper type shoveling ore into car hooked on behind. In the mining method used, the chutes have been pulled out and the ore has been allowed to run down onto the level to be shoveled up. One of the muck piles thus formed is here being attacked.

This hoe-type scraper folds up on being pulled back (left) and opens up again (right) to dig into the broken muck as soon as the haul rope is tightened. By folding, it avoids the shocks that would otherwise be experienced whenever the back of the blade strikes large ore fragments.

Trench scraping, shown here at Cleveland-Cliffs' Mather iron mine, Michigan, enables the ore train to dump its load sideways, car by car, into the trench at left, and return for more. Scraper hoist in foreground drags ore in trench on to grizzley seen over ore pocket (beneath scraper). Oversize lumps are broken.

By remote control man operating scraper hoist (left) can run it by pushbuttons while standing a considerable distance away. Thus he can better observe movements of the scraper.

Modern hoist console. Operating levers are easily worked. All instruments are close to hoistman.

SOME NEW HOISTS

Some New Hoists

An interesting hoist is the double-drum unit without a center bearing (to cut the fleet angle) built for the U S S R by two American firms (28). Omission of the bearing necessitated a heavier shaft.

To get a double-drum hoist with 12-ft. diameter drums into the underground hoist room of an Idaho mine, sectionalized construction was necessary. The drums were placed in tandem to reduce the fleet angle. A third machine, of by-cylindro conical-balanced single-drum type, recently installed, is hoisting 10 tons every 120 seconds from 2,200 ft.

To detect dangerous flaws in hoisting ropes by a series of non-destructive tests, the Dumont cable tester has been developed from the Cyclograph. The latter instrument makes use of the fact that the amount of energy absorbed by a body in the field of a coil carrying an alternating current depends on the material in the body and upon the internal structure of that material and its stresses. The tests have been encouraging. It is believed that the beginning of rope deterioration can be detected.

Proper Ventilation

Proper ventilation of mine workings is now recognized as good business (29). The idea is that the men will be more contented and do better work. It should also reduce the incidence of disease from dust and so benefit employees and company alike. Within its scope also come dust control, dehumidification and cooling. Summed up, it means supplying enough air of the right characteristics to make working conditions comfortable. At some mines the natural ventilation alone will do this. In general, however, mechanical ventilation is being widely used. Many large fans are in service. In Ontario, for example, at least 50 are to be found at 32 mines, the largest single unit having 200,000 cfm capacity.

The ease with which the axial-flow propeller-type fan can be installed and, when necessary, quickly reversed has made it popular as compared with the propeller fan. A fan manufacturer stated, however, that if efficiency is high when blowing, it will be comparatively low when exhausting, and that the capacity will be less in one case than in the other.

According to another maker, auxiliary ventilation has been standardized on an axial-flow fan 18 to 20 in. in diameter or a centrifugal fan of 5,000 to 6,000 cfm capacity. Still another holds that two types are necessary: a medium-pressure, axial-flow unit and a high-pressure centrifugal fan, if one is to get the most air for the least horsepower. When higher static pressures are wanted, because ventilating lines are longer or smaller pipe is desired without reducing the volume of air, the centrifugal blower is best fitted.

Why try to condition the air of an entire mine, it is asked, if a spot cooler in the warm place will be sufficient? To date, only a few such units have been installed, the war having interrupted the work. The idea expressed is sound. Where used, spot coolers have improved air conditions in dead ends and in places remote from the main air stream. In one mine, spot coolers are delivering 3,500 cfm through 4,000 ft of pipe to

Riddell shaft mucker seen from bottom of shaft. Carriage, which carries clamshell-bucket hoist and its motors, as well as the operator, rides back and forth on the two beams.

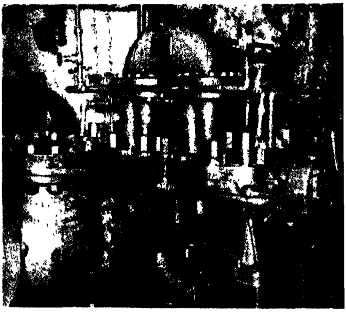
Operator on cage in mine shaft talks directly with hoistman on top. Voice receiver and transmitter are just over his head. Hoisting rope supporting cage carries fundamental frequency which can be modulated for voice transmission.

dead ends, discharging it at 79 per cent relative humidity, compared with 96 per cent at the intake. The cooling effect results from the lowered temperature and smaller quantity of water vapor.

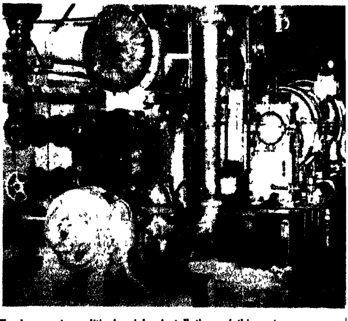
Soon a new 573,000 cfm cooling plant will be added to Magma Copper Co.'s present installation, one of the relatively small number of large refrigeration plants in the mining industry (30).

Aside from this, the most recent intallation of a system for refrigerating mine air, one put in by Noranda Mines (31) in Quebec, involves the cooling of mine air in the summer by passing it through an old stope filled with ice, formed during the winter by spraying water into the cold winter air entering the stope (31). A cost of about $0.07 per ton of refrigeration has been ex-

Large hoisting capacity features this single-drum unit. Every 120 seconds it brings 10 tons of limestone to surface from 2,200 ft. depth.



Centrifugal pumps handle most mine water today. This 4-stage, high-pressure unit in a large Western mine is driven by 500 hp. motor, handles 750 gpm against 1750 ft.



For larger air-conditioning jobs, installations of this sort are in order. This refrigeration unit consists of compressor, condenser and cooler, each run by a 200 hp. motor.

A spot cooler underground in a western copper mine. Why cool all the mine air when only an occasional spot needs such conditioning?

Blast holes 9 to 12 in. in diameter are being put down by this group of churn drills, as a step preparatory to further stripping.

pected, compared with 0 14 per ton obtained in Anaconda's novel dew-point cooling plant at Butte, and 0 37 to 0 52 in standard refrigeration plants at three mines in Brazil, South Africa, and Arizona, respectively

Pump Installations

Multi-stage centrifugal pumps today handle the bulk of the mine water that has to be lifted to surface Their chief new competition is coming from submersible turbine or deep-well pumps, especially for unwatering (32). Many mines have old, inefficient pumping layouts, the result of haphazard, unplanned growth Modernizing the layout and the pumps would probably save the operator money Repairs and replacements would be facilitated by standardizing, so far as possible, on pumps of one design and few sizes.

Current trends also include automatic instrumental control of power used in the plant to permit pumping on off-peak power (33), as practiced by Wright-Hargreaves, also automatic control of priming and other phases of pump operation Sump construction, to facilitate cleaning, is receiving attention. A gravity head on the pump insures against priming loss

Drainage ditches fill up Cleaning them has generally been a nuisance A ditch-cleaning machine recently introduced should prove a convenience It comprises a car that runs on the mine rails and carries the equipment for operating a scraper in a sloping trough at the side. The lower end of the trough fits in the ditch

Open-Cut Mining

The past decade has seen great changes in open-cut mining practice (34) This has centered on the adoption of heavy-duty trucks and belt conveyors, separately or in various combinations, to take the place of rail transport where conditions permit (35). Excavator lines, moreover, have been extended to include very large sizes. The size used, of course, must depend upon the job.

New competition confronts the churn drills and wagon drills that have long been the standard means of breaking ground ahead of the shovel or dragline A crawler-mounted piston-type air drill for drilling 5 in and larger holes, just introduced, will drill the 5 in. size about three times as fast as the churn drill Its first cost is considerably more than the latter machine

Another competitor is *fusion-piercing,* a process of making a blast hole with a blowpipe that produces temperatures up to 4000 deg F by burning oxygen with a petroleum-base fuel, which carries a flux (36) With this process and equipment, both developed by Linde Air Products Co, holes 6 in in diameter and 30 ft deep have been drilled in hard rock at an average rate of 10 ft per hour, compared with 1 ft with churn drills The pressure in the hole ejects the rock in granulated form with the vapor and gases

The size of churn-drill holes has been increasing in an effort to raise blasting efficiency While most holes drilled have been 5 to 6 in in diameter or smaller, in recent years 9 in holes have become quite common For the larger hole a larger and heavier bit is used. Most recently, hole size has gone to 12 in

Recent improvements in churn drills, aside from size, include built-in leveling jacks worked by valves from the operator's position, which save time in setting up; also a steel cab to make the drillman comfortable in bad weather

Both horizontal and vertical auger-type drills, either truck-mounted or self-propelled, for holes 6 in and bigger, are proving increasingly useful, the former for toe holes in the bank Operation is helped by a new mechanical self-feed.

Tungsten-carbide drill bits are being tried with wagon drills (9).

Blasting practice, already excellent, shows few recent improvements. Short-period delay detonators are useful in lessening noise and vibration, and give better fragmentation A new blasting machine will get the same results. Shaped charges are being tried in a western pit for breaking large fragments.

Large Excavators Larger

Draglines up to 25 cu yd in bucket capacity have been introduced in the last two or three years (37). Most recently, a 16 cu yd machine has appeared. All others have buckets not exceeding 9 or 10 cu yd in size and usually smaller. These big machines are of the

Horizontal auger drill putting a hole into the bank. This boring machine is self-propelled. The same machine may be had truck-mounted for greater mobility.

Up-to-date crawler-mounted, full-revolving electric shovel with 5 cu. yd. dipper loading 20 cu. yd. end-dump truck. Note shovelman's cab projecting at one side of boom.

Typical open-cut mining scene. Churn drills above are breaking ground ahead of shovel, which is loading truck. In foreground, tractor-bulldozer is cleaning up and in general assisting the shovel.

Modern heavy-duty truck for "off-the-highway" service is ruggedly built. This 30-ton capacity, 10-wheel giant has replaceable cast manganese-steel bottom lines and other features to match.

walking type which has a surer footing A trend to this type is apparent.

Shovels stick to dippers of moderate size Dippers of 10 cu yd capacity are used, but 4½ to 6 cu yd is customary in handling iron and copper ores The smaller size is better adapted to conditions Nothing comparable to the big 35 and 40 cu yd coal strippers is used in the metal and non-metal industry.

In building buckets and dippers, alloy steels containing manganese, nickel and other metals are finding greater use.

Excavators currently are either electrically operated or diesel-driven, with occasionally some combination of the two.

Automatic Controls

As with mine hoists, automatic controls figure importantly in operating the newer shovels and draglines, particularly in the very large sizes. With electric controls, small forces are made to control large ones, thus giving a delicacy of control not otherwise had. This also results in simpler control equipment

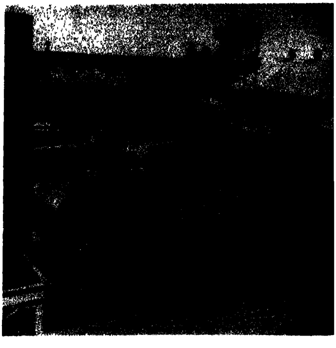
Although wheel scrapers are not extensively used in mining work, they have possibilities Where conditions favor them, stripping can be done more cheaply with them than with shovels and trucks Recently two new and faster models, having their own built-in power, have been introduced One will handle 17 5 cu yd at 18 mph and the other 3 3 cu yd at 23 mph

Open-Cut Haulage Practice

Haulage and transport in open-cut mining are still done with railroad equipment, where the distance hauled is considerable, the daily tonnage is large, reserves are big, and there is no urgent need for the ore in the track benches (38). Under such conditions, a minimum cost is obtained. Much steam equipment is still in service In opening a new large mine on the

Fast wheel-scraper with own built-in power. Its capacity is 17.5 cu. yd. Top speed is 18 mph.

Airborne magnetometer is trailed behind the airplane in making a geophysical survey. From the readings taken in flight from a height of several hundred feet, magnetic anomalies are determined for the sub-surface, a first step in exploration.



The gold mine clarifying tanks of the Crows-Merril Plant at Witwatersrand, South Africa.

Mesabi today, this type of transport would still be considered Where grades steepen, the diesel-electric locomotive offers advantages in lower operating and maintenance cost, greater availability, more traction. Straight electric locomotives are also still in the picture.

Despite the foregoing, heavy-duty trucks and conveyors have taken over a good part of the work formerly done with rail equipment. They are to be considered for every job Some mines use trucks exclusively. Others keep the trucks in the pit bottom, delivering the ore to a conveyor which lifts it out of the pit. For trucks this is the best practice.

Most trucks in off-the-highway service are of 15 to 20 ton capacity (34, 35). The 30 ton truck is increasing in numbers. The largest truck that takes the load "on its back" is of 40 ton capacity. Trailer-type trucks and semi-trailer types are extensively used The types of bodies are varied The trailer load is more hauled than carried, takes less power The trailer also is cheaper to replace

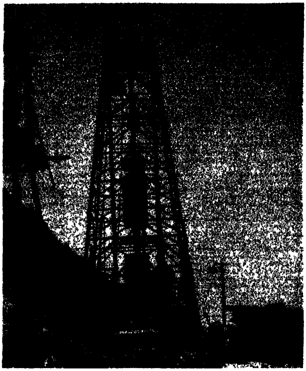
Trucks are largely diesel-powered In general, truck maintenance is proving a heavy task, where fleets are large

Conveyors vs. Trucks

The future will decide the extent to which the conveyor will displace the truck It seems likely that trucks will be kept in the pit where the tonnage is considerable The conveyor then will give cheap transport out of the pit, a task for which it is better suited Already there are about 16 conveyor installations in the Iron Country alone (35) Improved belt construction, moreover, is greatly improving the conveyor's ability to compete

Shaft Sinking

Holes 5 to 6 ft in diameter to depths as much as 2500 ft are readily bored today with improved shot-drilling technique and equipment (39) Holes of even larger diameter are talked of In mining work, such holes may be used for ventilation or may subsequently be enlarged by slabbing to serve as shafts A hole 48 in in diameter has also been made with churn drills Started at 12 in, it was reamed in steps to its present size, using hard-faced tools



Boring a 6-ft. diameter hole 1,400 ft. deep in Peru, using chilled shot in slot made by cutting tool. Driving apparatus and its operator follow tool down hole.

Still in the experimental stage this 12-cylinder, 550-hp. supercharged diesel is being tested on the Mesabi Iron Range of Minnesota. Fully loaded it weighs 80 tons.

Exploration

No part of mining practice exhibits a greater degree of modernization than the work of exploring for new ore deposits and drilling them when found This is doubtless due to the urgent need for new discoveries. All that science and technology have to offer, as understood at present, is being used to promote such work The airplane facilitates travel to remote places With it, work in the bush has been eased to a degree once only imagined Regions of the north and in the tropics are being mapped accurately from the air by photogrammetry, revealing their topographic and geologic features With the airborne magnetometer, geophysical surveys such as this instrument is capable of are being made of large areas at unprecedented speed and cost (40) Improvements in the use of other geophysical methods are promising Geochemistry (41) and spectroscopy are also being made to serve the mining industry

In exploration drilling, core recovery has been increased by improving the design of core barrels (42). Holes can be more accurately surveyed with instruments now available They can be straightened or deflected as desired The practice of wedging off new holes from a subsurface point on one already drilled is an outgrowth of this technique It saves footage, facilitates exploration

By all these means the outlook for exploiting and maintaining the world's supply of minerals has been much improved.

Illustrations for this chapter were obtained through the courtesy of Ingersoll-Rand Co., General Electric Co (British), Inland Steel Co., Eimco Co., Lake Shore Engineering Co, Allis-Chalmers Mfg. Co., Westinghouse Electric Corp, A E Dick Construction Co, Union of South Africa Government Information Office, P & H Harnischfeger Co., LaPlant-Choate Mfg Co, Euclid Road Machinery Co.

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CHAPTER XVIII

INDUSTRIAL PACKAGING

by A. C. DOLEZAL AND C. J. CARNEY, JR.

War-born techniques and products have given tremendous impetus to the industrial packaging field Many improvements in old protective packaging methods, plus the addition of new materials, now give increased product protection In many cases the merchandising appeal of manufactured goods has been heightened by the new combination of scientific protection and eye appeal.

Overshadowing and encompassing any of these factors, however, is the most significant development which has yet come to pass in the industrial packaging field, namely, the rise of the *Scientific Packaging* approach, and, coupled with it, the rapid growth of the profession of package engineering (1, 2, 3, 4)

Scientific Product Protection

For many years some of our leading commercial and industrial organizations have maintained staffs of specialists whom they have classified as "Packaging Engineers" (5). In connection with their Packaging Divisions, many of these companies have established testing laboratories wherein package designs and materials have been subjected to certain standard tests designed to indicate the merit of a particular type of specification (6, 7) Organizations like International Harvester, Sears Roebuck, Western Electric, General Electric, Eastman Kodak, General Motors, Anheuser-Busch, Montgomery Ward, Owens-Illinois Glass Company, to name a few, long ago recognized the value of a scientific approach to the solution of their packaging problems

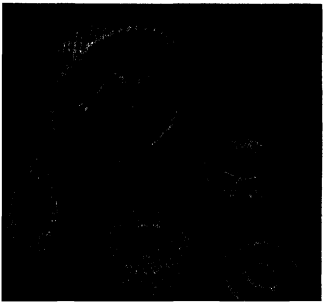
Today, in American industry, this *scientific approach* is more important than ever before (8) The pressure of business activity is greater, competition is keener; production problems, the intricacies of modern warehousing and distribution are more complex and result in greater hazards to all forms of packaged goods (9) The packaging engineer, having in the early days performed his job well, has earned greater responsibilities Today his duties occupy an important and pre-eminent place in the management pattern.

Evidences of Packaging Importance

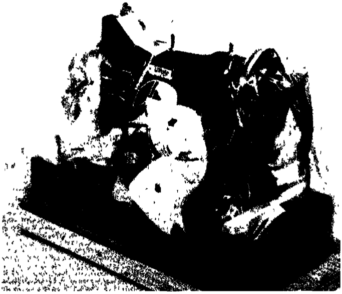
The growth of the Industrial Packaging Engineers Association bears witness to the important new place of scientific product protection Its membership has tripled during the recent postwar years Attendance at its Annual Exposition and Forum Sessions continues to grow Just this past fall, 115 executives, representatives of American commerce and industry at large, journeyed to Detroit from all parts of the country to sit in as students in I P E A's week-long Packaging and Material Handling Institute, which was conducted in cooperation with Detroit's Wayne University The railroads, truck lines, airlines, steamships, the great mercantile organizations, the automotive industry, everyone is "on the bandwagon" for better packaging

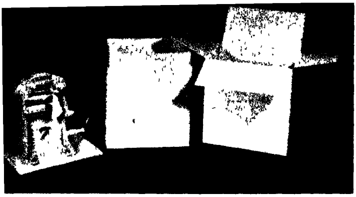
With this development of the *scientific* approach to packaging, the packaging engineer is often able to suggest changes in manufacturing methods or in product design which result in improvements in handling technique,

Metal parts packaged in removable ethylcellulose hot-melt dip become immunized against rust and other damage.

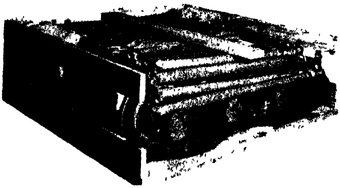


Ready for shipment and indefinite storage, this product has been sealed in a vaporproof and transparent bag.





Leather cutting machine is packaged assembled with component parts in reinforced carton to reduce weight.



Secure transit of heavy parts in wooden crates depends upon carefully packing to eliminate shifting of parts.

Nailed wooden box adapted to shipment of engines. Packing is done by moving box along conveyor line and assembling units with hoists. Shipping cubage as well as transportation hazards are reduced by compactness of the parts.

production speed, product perfection or other economies, because design and specification of shipping containers or other packaging are intimately related to or dependent upon the very nature of the item being transported or handled

Other elements which have an important bearing on determination of ultimate package design and specification are the following.

(a) Size of the article
(b) Weight of the article
(c) Fragility, perishability, inflammability, etc.
(d) Monetary value
(e) Handling and Transportation hazards
(f) Promotional aspects

The size and weight of the article to be packaged are important considerations in determining the nature of the packaging material to be used Fragility, perishability or inflammability determine what will be required in the specification of cushioning materials (10). As a matter of fact, perishability and inflammability, as well as fragility, frequently determine the mode of transportation as well as container type, and all three elements have an important bearing in the determination of the shipping labels which will be used

Cleaning and Corrosion Prevention

Prior to the war, cleaning and corrosion prevention treatment of metal objects particularly was little known or appreciated as packaging procedures (11). While not a primary packaging job, the cleaning of metal parts, for example, is the necessary requisite of a good package, especially in export shipment where loss and damage of precision equipment or machinery, due to rust and corrosion, are most noticeable Since the war, however, many manufacturers whose products are used entirely in the domestic market which may be warehoused for long periods or subjected to conditions which are conducive to corrosion and rust, have turned to product cleaning and anti-corrosion treatment as the first basic step in a thorough and complete packaging job The methods most used are:

(a) Alkaline spray.
(b) Solvent wash or dip.

The alkaline spray involves the use of chemicals which remove all types of contaminants, including fingerprints.

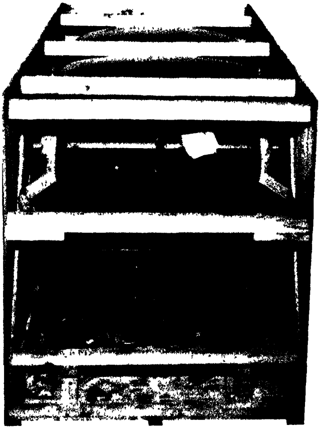
The solvent method is generally the simplest. This method involves dipping or bathing the object in a solution which will remove dirt and certain other contaminants, but it will not remove fingerprints.

Recently some manufacturers have been using an emulsified cleaning method which leaves a light protective coating on the article. This coating affords temporary protection against corrosion, but it is not adaptable to materials that are to be electroplated.

In conjunction with this particular method, the use of grease-proof, non-corrosive or anti-tarnish paper enables manufacturers to do a perfect pre-packaging job.

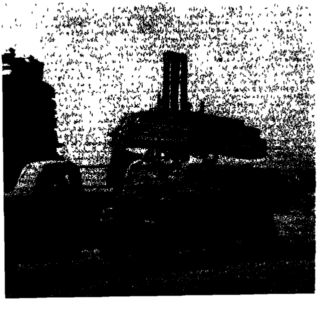
A wartime development, which combines certain properties of a cleaning compound with the protection afforded by a complete covering of the product, is ethyl cellulose coating (12, 13, 14). This method of preserving and packaging is especially adaptable to metal parts.

It consists essentially of dipping these parts in a tank of melted strip coating compound. The coating is formed around the metal part through the heat absorptivity of the metal which, in turn, causes the plastic to solidify around the part. Subsequent air cooling causes the plastic coating to set to a tough, waterproof, abrasion- and corrosion-resistant film.

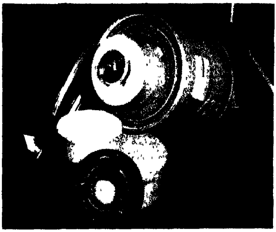


A truck cab anchored, braced and blocked in a nailed wooden box of latest design. Technique of construction includes diagonal reinforcements through various panels and the use of metal braces and steel strapping reinforcements to give additional strength.

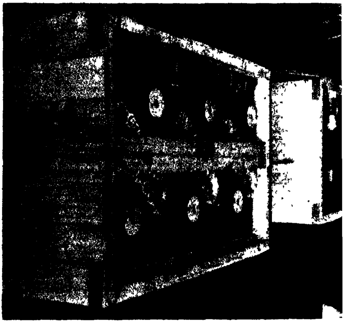
Steel strapping lumber into bundles results in savings in labor, time and money. It simplifies storing, tallying, shipping and reduces losses from theft.



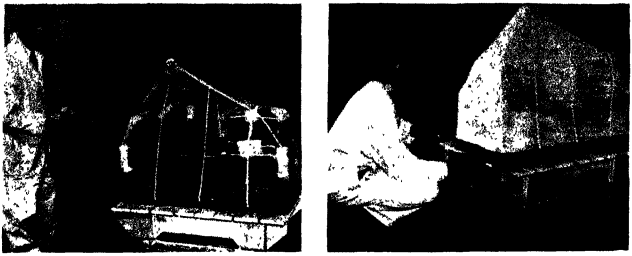
Bright chromium surfaces of appliances arrive at destination unmarred when covered by protective papers.



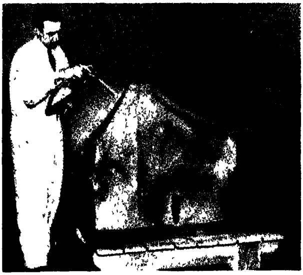
An Image Dissector tube for television is floated in fibre board drums, corrugate and shock-absorbent Kimpack.



Motor assemblies packed for export shipment in nailed wooden boxes with excelsior pads for cushioning agents.

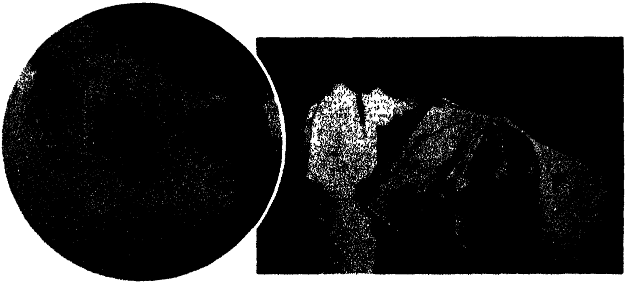


Sharp edges are covered with a soft material and sections of tape, about 20 in. apart, criss-crossed for support. Solution for first application forms spider-web filaments that adhere to the tape serving as a base for the wrapping.



First coating of the plastic cover is applied with an air gun. Yellow in color, it permits the operator to determine uniformity of application. Opening permits gas to escape or provides for ventilation.

Second coating is red to distinguish from yellow base. The third application generally consists of aluminum paint. When stored under severe conditions, Gilsonite is applied before painting with aluminum.



The interior of the packaged unit is kept dry with a silica gel. A thermometer and humidistat may also be provided, should careful control be required, as shown at left. The machine is packed ready for use because the plastic coatings are not applied to the surface. The cover is as easily removed as a paper wrapping.

Nailed Wooden Boxes

This oldest form of shipping container has been improved through application of new engineering methods. Weight and cubage have been reduced, while product protection has been increased. Reductions in lumber thicknesses have been made possible by proper application of steel wire or strapping re-enforcements (15, 16).

In a talk before the Industrial Packaging Engineers Association, Wayne University Packaging and Material Handling Institute, Mr. Wm. H. Sardo, Jr., Secretary of the National Wooden Box Association, listed the following noteworthy achievements in the wooden container field:

(a) Improvements in the construction of semi-nailed or lock-corner boxes through the use of war-developed, water-resistant adhesives.

(b) Development of wooden boxes and crates of so-called "nailless" type, which do not require the use of nails in the assembling of the shook into a completed shipping unit.

(c) New types of box end construction which permits edge-grain nailing around the four edges without the attachment of cleats, thus affording the strength of cleated construction with a minimum of cubic displacement.

(d) Development of lightweight wooden containers for the shipment of pre-packaged fruits and vegetables.

(e) Use of plastic treatments for reusable wooden boxes, such as beer and soft drink cases and field picking crates, which resist rot and decay of the wood fibres and control the dimensional changes of the wooden parts.

Wirebound Boxes

Wirebound boxes, which are containers manufactured from veneer stock, and which are re-enforced and bound together with certain gauges of steel wire, have won wide acceptance in recent years. Their chief benefits are that they combine light weight with great strength and shock-proofing qualities. Wirebound boxes can be engineered to a degree which makes them an extremely versatile container. They combine elements of flexibility and rigidity which can be emphasized in the container design to suit the choice of the packaging engineer. These boxes are adaptable both to domestic and export use and can now be made to almost any shape or size (17, 18, 19).

Fibreboard Boxes

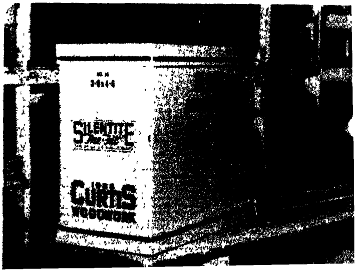
Quite remarkable advances have been made in the fibreboard container field during the past nine years. The development of water-resistant, corrugated and solid fibreboard is perhaps the most important single advancement made in the industrial packaging field. Of course, the stringent requirements of war-time fibreboard containers have been relaxed in keeping with peace-time needs.

Corrugated fibreboard is improving in quality and, even now, is being manufactured to a bursting strength of from 500 to 800 pounds per square inch. The merchandising potential of fibreboard containers is being exploited with increasing effectiveness. Judicious use of colored boards, together with special care in color de-

Completed bundle of window sash is ready for the assembly of the heads before placing the lid in position.

Operator demonstrates simple operation of placing the lid in position. Tool holds it in place for strapping.

Finished container has 4 thicknesses of material between sash and strap. Pressure of straps assures tight fit and prevents shifting of the sash within the package.



sign and printing processes, is winning increasing attention because of its display value by fibreboard consumers (20, 21)

Cushioning Materials

The need for protecting many types of products which may be easily broken has placed new emphasis on the requirements of special cushioning materials (22, 23). Widely used at the present time are cellulose waddings, groundwood pads, macerated news blankets, and cotton wadding blankets. An old form of cushioning material, wood excelsior, is appearing in new garb in the form of sealed end pads, blankets, and tubes All of these forms and types of cushioning material have found a wider acceptance since the advent of trained packaging engineers who determine the specific need for the qualities inherent in each form of cushioning material

Non-Hygroscopic Tape

Another development directly traceable to war-time needs is the development of a waterproof adhesive tape which is intended for use as a moisture-proof covering and for sealing openings in containers or parts (24, 25) This tape finds its principal applications in preventing salt or moisture air and other harmful elements from coming in contact with metal parts. Another use for this tape is to fasten shipping stickers to metal objects, such as castings and forgings which are generally difficult to identify.

Plastic and Desiccant Plugs

One of the simplest packaging devices developed during the war and now being successfully used in any product which can be sealed off to form its own packaging unit is the plastic plug which contains a desiccant or drying agent, such as silica gel (26) The use of this plug keeps moisture from entering the unit Silica gel readily absorbs moisture which may accumulate within the sealed unit as a result of temperature changes

Protective Covers

Plastic films have been developed that are especially resistant to moisture penetration, temperature changes, and rough handling In addition, older types of paper over-wraps (27), shipping bags, etc, are now treated with various chemicals which make them water repellent and puncture resistant (28, 29)

An outstanding development is a protective coating which can be applied by use of compressed air and spray gun This material is applicable to anything from a huge generator or tractor to the smallest of parts, such as a small ball or roller bearing (30). Once packaged, they can be shipped any distance, or they can be stored indefinitely in the open, secure against rain, snow, mold, bacteria, etc In using this type of coating, a suitable desiccant or drying agent is sealed within the unit to absorb moisture which may occur through temperature changes The plastic coating does not adhere to the protected unit, and when necessary, may be peeled away in a few minutes

The industrial packaging field has come a long way from the day when it was thought sufficient to throw a few pieces of wood together in the form of a crude box This is an age of specialization, and the development of specialized techniques for the packaging of industrial products is a comparatively new science (31, 32). Undoubtedly, however, we have just scratched the surface, and many more interesting improvements will be announced within the next few years (33, 34).

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CHAPTER XIX

PAPER AND PULP INDUSTRY

by RONALD G. MACDONALD

A review of the pulp and paper industry reveals a steady expansion of production facilities to meet the increasing demands for paper and paper board products European production dropped due to destruction of mills during the war, but the expansion in the United States and Canada has now offset these losses in world production capacity The United States and Canada were responsible for some 55 per cent of world production of paper in 1937 but in 1946 this figure had increased to about 77 per cent United States paper production alone has more than doubled in the past 15 years from about 9½ million tons in 1931 to over 19 million tons in 1946

While established uses for paper products have continued to grow, many new applications have been developed During the war, paper found itself a universal substitute While its uses were innumerable, one of the most pressing needs was for improved packages that could stand up to the rigors of overseas shipments for war This led to an integrated research program resulting in the production of V-boxes and other packaging improvements Although production of such materials was cut back at the end of the war, the civilian demand has more than taken up the slack The increased requirements for nearly all types of paper and paperboard have been largely responsible for the expansion throughout all the paper producing sections of the country

Closely linked with the physical expansion of the industry is the technological progress that has made possible many advances All phases of the industry have participated in technological developments and profited from better quality products, higher efficiencies and greater production

Technology and Research

Fundamental chemical research has been largely directed toward a better understanding of the chemical structure of the components of wood such as cellulose, lignin, etc Further utilization of chemical substances, now largely wasted, has been widely studied. Production of yeast, alcohol, vanillin, turpentine, tall oil, lignin plastic materials and bark products has become technologically and, in some cases, economically feasible.

Most industrial research and development programs have been directed toward improving processes by new techniques as well as new and improved equipment Much of the progress here has paralleled developments in other industries. For instance, the trend toward greater use of industrial measurement and control instruments is notable. Other industries such as petroleum and chemical processing have been leaders in instrumentation But in recent years the pulp and paper industry has become increasingly aware of the advantages of instrumentation and many of the new installations are fully equipped with automatic controls

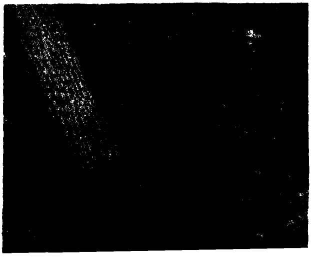
In general, process and equipment improvements have taken place in all phases of operation and in all branches of the industry While these are too numerous to be discussed in detail, the more important trends and developments will be outlined briefly

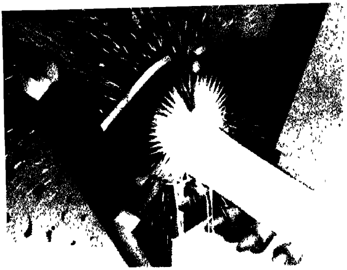
Pulp Wood (1-11)

One of nature's most widespread and most easily available reservoirs, wood has always been a major industrial raw material Nevertheless, except in large scale logging encountered mainly on the West Coast, woods operations have, until recent years, remained rather primitive Pulpwood production methods had received little attention However, the conditions of war helped focus attention on this phase of the industry Motivated by the nationwide labor shortage which stripped the woods of men, mechanical power equipment took over many traditionally manual jobs Much of this equipment was available before 1941 and needed only the impetus of war conditions to foster its widespread use.

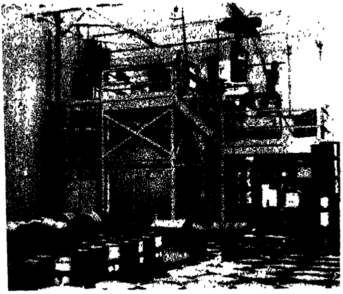
Power driven saws became a *must* for efficient woods operations Portable pulpwood mills with mechanical conveying and handling equipment have found increasing application, and in some instances have lowered production costs markedly Greater use of tractors, wood carriers, truck loading equipment, self loading trucks, sulkies for wood skidding and similar logging equipment have helped woods operations attain an efficiency heretofore impossible.

Development of power driven saws and other mechanical equipment has helped modernize logging operations.





As logs pass through hydraulic barker, high-velocity water jets strip the bark cleanly from the wood.



Bleach liquor made here (based on sodium peroxide) is used to bleach mixtures of groundwood and sulphite.

High-density pulp is continuously mixed with peroxide bleach liquor before going to the bleaching tower.

A most important development in increasing yields and in decreasing waste is the hydraulic barker Several West Coast mills participated in this development, which, beginning in 1935, resulted in a log peeling device now responsible for a tremendous reduction of wood waste and an appreciable saving of labor Based on the use of high-velocity water jets for stripping the wood of its bark, some of these machines require water pressures up to nearly 1,500 lb per sq in Different types of log handling equipment are used, some of which can accommodate logs over 30 ft long and up to 72 in in diameter While many of the units in use were engineered and built by the users, hydraulic barkers are commercially available in standard models from several equipment manufacturers

The hydraulic barker was made possible by development of water pressures sufficiently great to remove bark by this method Multistage pumps are available for delivering from 900 to 1,500 gal of water per minute at pressures up to 1,500 lb per sq in

Improved high speed multi-knife chippers have largely supplanted the older types of machines in modern installations to produce more uniform chips at a high rate Chippers with disks nearly 15 ft in diameter powered by 1,500 hp synchronous motors are now in use Higher quality steels have made possible better knives and wearing plates A new horizontal chipper is now being operated to produce chips of greater uniformity than heretofore possible

Mechanical Pulp (12-17)

Production of groundwood pulp has seen several developments that have added to its usefulness Greater economy and quality have resulted from improved grinding equipment while wider usefulness has been brought about by the development of bleaching methods that have proved satisfactory for this kind of pulp Inherently lower in cost than chemical pulps, because of high yields, groundwood utilization is just coming into its own

Replacement of natural stone by artificial or manufactured stone has been partly responsible for increasing the speeds and pressures of grinding operations. The Roberts grinder and the improved hydraulic magazine type grinders now in use have made possible new standards of efficiency and economy and, in new installations, these improved types of machines are usually selected instead of the old multipocket grinders

Waste reduction has been made possible by use of disk and other types of refiners to process groundwood tailings and screenings that would otherwise be discarded or burned This treatment, bringing more complete utilization of material otherwise wasted, has been instrumental in improving the overall efficiency of a number of plants.

Perhaps the greatest advance in mechanical pulping is in the development of practical methods of producing bleached groundwood pulp. Noteworthy is the peroxide process which has made possible the production of large tonnages of paper with higher brightness and better printing qualities than paper containing ordinary groundwood pulp. Several mills have installed peroxide bleaching systems.

Based on sodium peroxide, the process consists of mixing bleaching liquor with slush pulp (at a consistency of 4-5 per cent) in controlled proportions, allowing the mixture to stand long enough for bleaching to take place and then neutralizing any excess peroxide Since the non-cellulosic constituents of the pulp are not removed by the peroxide treatment, there is little weight loss in this bleaching process

Groundwood pulp, bleached by this process, retains its desirable characteristics for producing papers of good bulk, high opacity, and good printing qualities, and to these are added improved color, brightness and better permanence It may be used to advantage in many of the papers that employ unbleached groundwood In addition, it is finding new uses in machine coated book and magazine papers Another development is the zinc hydrosulphite process for bleaching groundwood It is now in use by at least one manufacturer

Most important research is in the use of hardwoods to make mechanical pulp In many parts of the country soft wood forests are badly depleted but large supplies of hardwood are available Ordinary grinding procedures result in complete mechanical breakdown of the fiber Steaming of the wood in autoclaves at high pressure in the presence of different chemicals has been found to modify and soften the wood so that it can be successfully ground Commercial application of this type of process will probably take place in the near future

Semi-chemical Pulp (18-20)

In recent years semi-chemical pulps have come into general use for producing insulating and other coarse boards High yields are obtained by giving the wood a partial cooking followed by disintegration This type of pulp may result from processes using steam alone to the use of relatively strong chemical liquors, usually alkaline. Disintegration may be accomplished in a variety of machines such as hammermills, grinders, jordans and refiners Semi-chemical pulps are now successfully produced by a continuous process

Semi-chemical pulps have the advantage of high yields and low chemical usage Lignin and hemicellulose are only partially removed and the pulps so produced are usually of high strength but low color Since bleaching is difficult and expensive, this type of pulp will continue to be used in unbleached products

Sulphite Pulp (21-32)

Progress in sulphite pulping has resulted from a number of technological developments New techniques, new types of equipment and modified processes have appeared during recent years in which practically all phases of this process have undergone improvements.

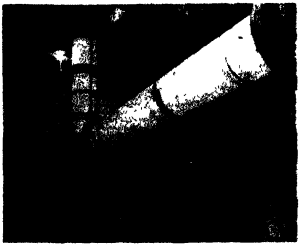
Cooking acid manufacture has benefited from the development of new types of sulphur melters, burners, and coolers. Improved melting and metering of the feed to the sulphur burners together with better control of secondary air has led to more uniform burner gas. Pressure absorption of gas, adoption of hot acid accumulators and acid storage under pressure have resulted in more uniform, higher strength cooking acid. This in turn improves cooking operations and the quality of pulp.

Application of indirect heating and acid circulation is becoming more common The production capacity of many mills has been improved by packing the chips in the digester This is aided by the forced circulation liquor system Increased production capacity per digester is due to all these factors, namely increased acid strength indirect heating, forced circulation and chip packing In addition, blow heat and gas recovery has been practiced in some plants to achieve higher efficiencies Some 50 per cent of the total heat in the sulphite cooking process may be thus recoverable Undoubtedly, the greater use of automatic control instruments has contributed greatly to the advances made in this field

New types of knotters and improved screens are finding widespread use The Jonsson knotter has been installed in many mills The new Cowan screen has increased screen capacity and reduced decker loads Rubber lined or stainless steel vacuum filters are used for washing brown stock prior to the screens Various types of corrosion resistant metals are finding value in screen plates, vats, washers and other similar equipment.

Treatment of waste liquor has long been a problem of the sulphite process A number of utilization methods have been developed including production of yeast, vanillin, and ethyl alcohol Two new processes have been developed which seem to hold much promise for the future The magnesium base sulphite process has undergone extensive pilot plant tests and a full commercial plant will soon go into operation Here magnesium replaces calcium as the base for the cooking liquor wherein the waste black liquor is evaporated and burned in a manner similar to the sulphate (kraft) recovery process Ash from the smelter consists mainly of magnesium oxide, which is made into a slurry for absorbing sulphur dioxide to form the fresh cooking liquor High operating efficiencies are claimed for this process which utilizes the energy value of the organic waste and recovers a large portion of the active chemicals in the cooking liquor One of the most important features of this process is that it eliminates the problem of waste disposal

Transite pipe has gained wide acceptance in pulp and paper mills: corrosion resistance is important.



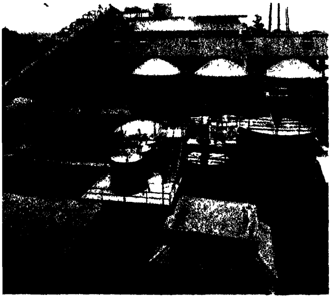
Another process now in commercial operation is a modified sulphite system where the calcium base is replaced by ammonia. This is used to make dissolving pulps and is claimed to result in improved quality. In one plant, considerable work has been done in developing a system for burning the waste liquor but no recovery of heat or chemicals is accomplished.

Sulphate (Kraft) Pulp (33-41)

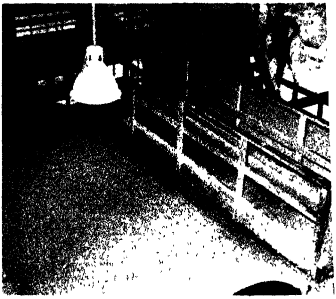
The trend in pulp and paper expansion is toward increasing application of the sulphate process. Improvement in techniques of producing sulphate pulp has made it possible to utilize species of wood not successfully treated by the sulphite process. Probably the most important factor in this field is bleaching. Ability to bleach sulphate pulp has been instrumental in increasing its usefulness in specialty papers of all kinds.

Multistage bleaching and washing with caustic extraction is necessary to produce a product with sufficient brightness to be competitive with bleached sulphite. High density bleaching stages at consistencies in the range of 12 to 20 per cent are now used for both sulphate and sulphite pulp. While cost of bleaching sulphate is higher than for sulphite, this is largely offset by the lower cost of the unbleached sulphate over sulphite.

Both stationary and rotary digesters are used for sulphate. New installations of both are underway. Carbon linings have been installed in a number of sulphate digesters in both southern and northern mills while ro-

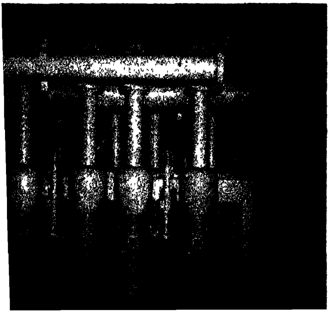


Continuous causticizing and clarification systems are widely used in making sulphate cooking liquor.

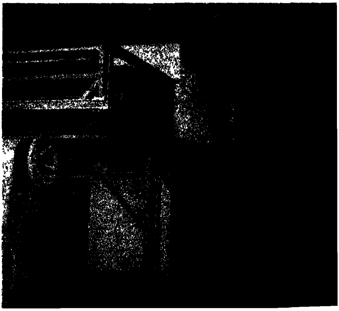


Vacuum thickeners remove water from slush pulp in preparation for high-consistency bleaching operations.

Dirtec units can replace screens for removing dirt particles from stock before it goes to paper machine.



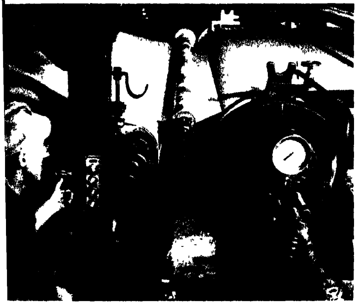
Four hot-air heaters maintain the temperature in this single-pass tunnel dryer for drying coated paper.



tary digesters now under construction will have chromium alloy liners Stainless steel of various compositions is finding increasing application in both acid and alkaline pulping process equipment Digester fittings, condenser tubes and headers, heaters, pumps and other similar equipment made of stainless steel are finding general acceptance

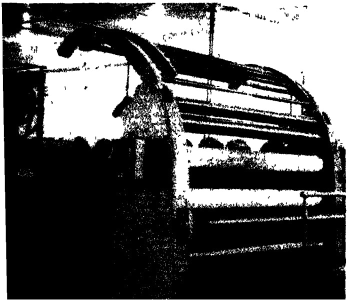
New plants and many old ones have installed continuous liquor making systems Continuous causticizing and clarification of the liquor has done much to put liquor manufacture on a more efficient basis

Rotary vacuum washers have pretty much replaced diffusers although a number of mills (especially Scandinavian mills) still prefer them All new mills are built with modern washing and screening systems Developments in knotters and screens have improved efficiencies and cut down stock losses Better control of liquor recovery improves evaporator operation Multistage evaporators are designed to operate under higher vacuum with a trend toward use of stainless steel tubes and stainless clad heaters in one or two stages at the strong liquor end of the system



Electronic regulators permit easy adjustment of the draw or tension between sections of paper machine.

After leaving the tunnel dryer, moisture content of the coated paper is automatically measured and recorded.



Evolution of the modern recovery furnace has generally followed the developments in the steam boiler field High pressure steam at good efficiencies from recovery furnaces has been the result of this progress In many mills, a good percentage of the steam load is carried by recovery furnaces

Electrostatic precipitators are widely used to prevent the loss of chemical dust from the recovery furnaces and have supplanted scrubber type units in many cases However, a new type of scrubber, operating on a pilot plant scale, is claimed to reduce salt cake losses to a new low This unit (Pease-Anthony) consists of a high velocity venturi tube with liquor sprays at the throat Waste gases pass at high velocity through the venturi to a cyclone scrubber and then to the stack Efficiencies of over 90 per cent soda recovery have been attained in pilot plant operation

Soda Pulp

Generally, the developments in soda pulp are similar to those of the sulphate process due to the fact that the two processes are closely related. Soda pulp production is relatively small, less than 5 per cent of total pulp turned out in this country, and technological changes are not as rapid as in the sulphite or sulphate processes Nevertheless, modern soda mills compare favorably with those using other processes

Paper Making (42-47)

While paper making has undergone few basic changes, there have been a number of improvements Continuous stock preparation is of wide interest and there is a trend away from batch methods The old Hollander type beater, so widely and universally used in the past has given way to the modern refiners New dirt removal equipment and improved screens have raised the quality of pulp going onto this machine Various modifications of headbox and slice design, notably the high pressure slice, have been partly responsible for increased machine speeds Progress in machine design is apparent in the form of new wet end shakes, larger table rolls, improved suction boxes, suction couch and suction presses with rubber covered rolls These all contribute to greater production and improved operating efficiencies

Although paper machine drives have progressed far, many of the older mills still operate with the mechanical drives of 30 years ago Sectional electric drives and improved mechanical drives have moved in gradually during the past century and have done much to increase speeds and improve production

One of the most important trends in the book and magazine paper field is in the manufacture of machine coated papers Although machine coating is over 10 years old, the increased demand for more and better coated papers spurred this development until now a number of book and magazine paper mills have installed or are planning to install this process Formerly, the coating process was completely separated from paper making In machine coating, the sheet is formed and dried before passing directly through the coating rolls It then passes through a second section of dryers to be wound on the reel as finished coated stock Supercalendering has also been improved by use of better bearings and better constructed rolls Supercalender speeds as high as 1,800 ft per min are now possible.

The trend toward greater speeds has also brought about improvements in drying Many new systems have been introduced to remove condensate from the dryers and to control the rate of drying Machine ventilation has been improved by various new systems

Development of wet strength papers has resulted from the combined efforts of paper technologists and those of the resin producers In the late 1930's a process was evolved to produce wet strength paper by use of small quantities of resin which upon drying polymerize to impart wet strength to the paper Since then research has brought forth improved resins and improved means of application until now wet strength papers are produced in large quantities and have found wide acceptance

Illustrations for this chapter were supplied through the courtesy of Newton Falls Paper Co, St Regis Paper Co, The Dow Co, Westinghouse Electric Corp, Johns-Manville Co, Worthington Pump & Machinery Corp.

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CHAPTER XX

PAINT, VARNISH AND LACQUER INDUSTRIES

by G. G. SWARD

The scientific and industrial worlds recognize the basic importance of paint and varnish. Numerous universities are offering courses in paint and varnish chemistry Manufacturers are establishing or enlarging research laboratories The American Society for Testing Materials came to this industry for its Edgar Marburg lecture for 1946. In this lecture, Mattiello (1) gave an excellent account of the role of paint and allied products as engineering materials More briefly, and in a less technical style, Kinsman reviewed the role of the chemist in the industry since 1915 (2)

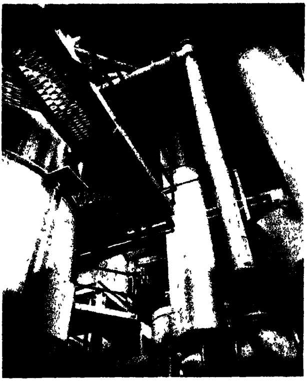
During the twenty-five years ending with Mattiello's lecture, drying oils retained their place as the basic raw material for paint, but the family of oils was enlarged by the addition of oiticica, soybean, and dehydrated castor oils, oils modified by treatment with phthalic or maleic acid, or modified by shifting double bonds to a conjugated position (isomerizing), fractionated oils; and re-esterified oils (esters of fatty acids and pentaerythritol and sorbitol).

In the same period, synthetic resins assumed the lead over natural resins Glycerol and pentaerythritol esters now account for most of the rosin used in the industry. Phenolic, alkyd, urea and melamine resins, and cellulosic lacquers have become commonplace Technologists are becoming familiar with specialties, such as vinyl resin, chlorinated rubber and butadiene polymers

Titanium dioxide, available only in the form of a composite pigment twenty-five years ago, is now the dominant white pigment It comes in two crystal forms, anatase and rutile Other pigments, born or matured in this period, are zinc yellow, phthalocyanine blue, alkali-resistant iron blue, translucent iron oxide, ferrous ammonium phosphate, phosphotungstomolybdate toners, lead aluminate, lead silicate.

Improvement in House Paint

On account of wartime shortages of drying oils, an important principle of exterior paint composition was put into wide practice. It had long been known that paints containing bodied oil gave smoother films and had longer useful life This knowledge prepared the way for WPB Order M-332 in 1943, that limits the amount of oil in one gallon of exterior paint to not over 3¾ pounds. The vehicle conforming to this order was known as linseed replacement oil (3) and contained approximately 1 part raw linseed oil, 1 part bodied (Z2 to Z4) linseed oil and 1 part thinner. The order was revoked as of August 31, 1945 However, so satisfactory was this vehicle that many paint manufacturers may continue to use substantial proportions of bodied oil in exterior paint (4, 5).



Lower view of castor oil dehydration installation, using high vacuum and temperature to change molecular structure.

New Drying Oil Derivatives

Economic and political conditions give no assurance that an adequate supply of linseed oil will continue to be available Steps to improve the supply are centered mainly on utilizing soybean oil and many physical and chemical processes for shortening its drying time in varnishes are now in use or proposed (6). These include extraction of the non-drying portions of bodied oils; solvent fractionation of raw oils, using furfural, and propane; fractional distillation of fatty acids followed by esterification; esterification with higher alcohols; substitution of fatty acids with resinifying groups, modification of the fatty acid; copolymerization with reactive monomers; and isomerization of isolated double bonds to a conjugated position An effective catalyst for isomerization is nickel deposited on carbon (7). Isomerized soybean and linseed oils body faster in the varnish kettle, dry faster and have better alkali resistance than alkali refined oils (8).

Drying Oil Studies

Advances are not limited to practical uses of drying oils since researchers have given substantial portions of their time to theory Chromatographic methods of separating fatty acids or their methyl esters into various types are an important aid to research in drying oils. A special silica separates the branched from unbranched, and saturated from unsaturated types. Following their separation, activated carbon separates each group according to molecular weight (9)

On the assumption (a) that linoleic and linolenic acids react with equal ease and (b) that the acids are randomly distributed among the glycerides, the iodine numbers of thermally polymerized linseed, tung, and soybean oils indicate that polymerization is a second order reaction (10). Other data, however, indicate that polymerization of vegetable oils, especially at relatively low temperatures, proceeds according to the degree of unsaturation of the oils; that is, the most highly unsaturated molecules polymerize first. Dimers, trimers, etc form in sequence. The polymerized oil can be separated into fractions by means of solvents, such as acetone, to yield non-drying and drying fractions (11)

When methyl esters of tung acids or fish acids are copolymerized with those of soya acids or stearic acid, the amount of polymer is greater than accounted for by separate polymerization (12) When two fatty acid groups of linseed oil polymerize, they form 6-carbon atom rings that take on aromatic properties as a result of further shifts in double bonds (13). Catalysts of polymerization probably function by conjugating the double bonds (14) Double bonds enable oil molecules to polymerize, but having reached a certain size, the polymer becomes immobile. Oxygen then splits the molecule at remaining double bonds. To obtain durable films it is necessary to have fast-drying esters of unsaturated acids with a small number of double bonds, and to establish drying conditions that use up the double bonds (15).

Recent theories regarding the mechanism of oxidation of double bonds postulate the existence of active hydrogen in the $-CH_2$ group between double bonds in the grouping $-CH{:}CH.CH_2.CH{:}CH-$. This theory has received additional support (16, 17). When linseed oil is air-blown, it shows a steady change in properties. On the other hand the changes in sardine oil fluctuate in the early part of the blowing (18), becoming steady in the later stages, and indicate stepwise the oxidation of the 5-double bond acids. A new characteristic for following the oxidation of linseed oil is called the Aluminum Number (19). It is the amount of aluminum isobutyrate that reacts with the α-ketoles and -diketones present in one gram of oxidized oil.

Synthetic Resins and Filmogens

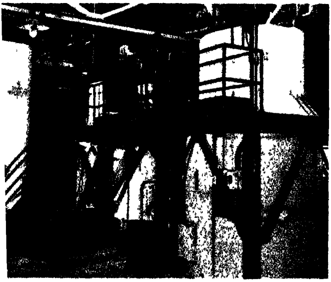
Use of styrene and vinyl polymers is expanding rapidly Copolymers of styrene and drying oils (20) are neutral, have good color, do not wet pigments very well, but suspend them excellently. They have good water resistance and electrical properties Vinyl resin dispersions in volatile organic liquids and in plasticizers are now available for the formulator (21) Dispersion in volatile liquids offers the same rapid drying as aqueous dispersions but with somewhat easier manufacture and control over properties On the other hand, synthetic rubber of the perbunan type, buna-S and butyl rubber have been found to possess no advantages over other filmogens now in use (22)

Flexibility of formulations may be greatly extended by recent studies of aqueous dispersions (23) Directions for making paints from Acrysol, Geon and Saran dispersions include suggestions for types of emulsifiers, plasticizers and pigments. Adhesion to rough surfaces is excellent but special techniques are necessary to obtain adhesion to smooth surfaces, such as glass

Hard, fast-drying resins of low acid number result when a glycerol-amine replaces a part of the glycerol in the preparation of alkyd resins (24). A method for preparing dibasic acids for polyamides is to add a small amount of water to the fatty acids and polymerize them under pressure. The process also separates linoleic from oleic acid (25).

By correlating the acid value and viscosity of alkyd

Automatically heated in esterfication kettles, tall oil fatty acid is processed for esterfied tall oil.



Diesel muffler at left withstands high temperatures when painted with silicone aluminum paint.

resins at their gel point, it is now possible to predict the approximate acid value (+3) of the finished resin (26). This procedure should be of great value to the industrial formulator of resins To supplement the supply of naphthalene used in making phthalic anhydride, producers are making use of ortho-xylene as a raw material (27)

Knowledge of allyl starch has been extended Films shrink during drying and develop numerous fine cracks. Suitably plasticized films do not shrink Lacquers with 50 per cent solids are practical and may be adjusted for spray or brush application. They are heat reactive but will cure at room temperature, if catalyzed with cobalt naphthenate Allyl starch lacquers develop high resistance to abrasion but retain good cold check resistance if suitable plasticizers have been used The allyl group has also been used to modify rosin esters (28) The modified resins are suitable for use in cellulose nitrate lacquers, and in oleoresinous varnish

Cellulose nitrate lacquers now constitute about 30 per cent of industrial finishes Developments that may increase this percentage are high solids-, hot application-, and fire retardant-lacquers (29). Plasticizers for cellulose nitrate have few secrets since the appearance of a comprehensive study of the Chicago Production Club (30) Not only are the usual characteristics such as specific gravity, boiling point, flash point, acid number, etc, given, but many others, such as their effects on electrical properties, color, and ultraviolet transmission of the films were determined Additional data on formulation of cellulosic lacquers shows that the long oil alkyds require less plasticizers, have lower initial gloss, but take a higher polish (31)

Extremely thick one-coat films can be obtained by the gel technique (32) The lacquer for this is fluid at about 120 deg. F but sets to a gel at room temperature, without sagging or running The base of such lacquers is cellulose aceto-butyrate or aceto-propionate Adhesion is not particularly good but shrinkage during drying tightens the film over articles that are coated on all sides An extension of this idea is melt coatings in which no solvent is used (33) Cellulose acetate-butyrate of high butyryl content (over 47) is the base of this product.

Progress is being made in adapting silicones to paints and varnishes (34) Their greatest use is in electrical insulation and in heat resistant coatings. Silicone and alkyd-silicones have remarkable resistance to many dilute acids and alkalis The alkyd-silicones are made by condensation and have excellent balance of hardness, toughness and adhesion Baking gives the best results. Pigmentation techniques are being investigated (35, 36).

Driers

A thorough study of driers has allowed some rules of drier action to be drawn (37) In the trivalent state manganese and cobalt accelerate drying more than in the bivalent state The catalytic power of chromium, iron, cobalt, manganese and nickel depends on reducibility from the trivalent state, which increases in the order named It also depends on the proportion of the metal present in the trivalent state which decreases in the same order From the product of the two factors the catalytic power increases from chromium to cobalt and then decreases to nickel Reactions among peroxides and the trivalent and bivalent states of the metals become very complex, and may reduce drying rates. Drying rates of cobalt and of manganese, under certain conditions, are proportional to the square root of the concentration Preliminary data (38) indicate that octoate driers are equal to or better than naphthenate in clear vehicles, slightly superior in white products and slightly inferior in black products.

Antioxidants and Antiskinners

Delaying the antioxidant effect of phenolic compounds in oil base paints by introducing the phenols in the form of the metal phenolates was suggested in 1932 (39) Accelerated weathering tests now show that the idea may be practical (40). Twenty-eight compounds have been examined (some for the first time) for their

Accurately weighing liquid ingredients in preparation for loading of roller mills in the manufacture of paints.

Development of new resin-based protective coatings starts with experimental batches in the flask stage.

antiskinning effect (41) Some of them were effective without appreciably interfering with the drying time of the varnish.

Antifouling Paint

Hot plastic antifouling paint (42) enables ships to remain at sea upwards of 18 months These paints incorporate the discovery that the toxic (cuprous oxide) must be leached at the rate of 10 micrograms per sq cm per day in order to prevent fouling (43, 44). If the pigment volume is below 30 per cent, the binder must gradually dissolve in order to expose more toxic In 1943 the U S Navy standardized on hot plastic antifouling paint, but has not yet made public its formula. These hot plastic paints are too heavy for the hulls of flying boats, for which a special paint was provided (45) A large percentage of mercurous chloride is used to impart satisfactory antifouling properties

Anticorrosive Paint

Important findings of the Corrosion Committee sponsored jointly by the American Iron and Steel Institute and British Iron and Steel Research Association are now appearing This committee has been conducting field tests in many parts of the world on several types of iron and steel, unprotected and protected, with metallic coatings and paint Recommendations for protection of various types of steelwork have been made (46) A report of the Marine Corrosion Sub-Committee confirms and enlarges earlier reports (47, 48)

Multipigment paints are superior to single pigment or two pigment paints for general marine conditions Paints with 3 or more pigments are superior to those made with 1 or 2 pigments A paint for general use is made with basic lead sulfate, basic lead carbonate, Burntisland red and barytes, modified phenol-formaldehyde resin and litho oil In three series of tests, 275 paints were tested In the United States, experiments show the (49) superiority of multi-pigment paints containing red lead over those containing no red lead, such as Navy Specification 52-P-18

A metal pretreatment developed for the U S Navy during the war consists of polyvinyl butyral, and phosphoric acid, dissolved in alcohol It dries to a hard tough film but is not to be looked upon as a replacement for the primer (50) U S Navy experience shows that on rusty surfaces, linseed oil vehicles give better service than alkyds, probably because the oil wets the rust more readily (51). When time does not allow an oil paint to dry thoroughly, priming the rusty iron with linseed oil and wiping off the excess gives increased durability On the other hand, the war-time alkyd paints of the Navy gave the expected service when they were applied to properly cleaned metal Film thickness is an important factor in the service given by paint on metal, especially ships. For example, Navy experience was that 4-coat systems of primer and top coat gave results superior to any 2-coat systems. The 4-coat systems were 5 to 6 mils thick. Thicker films were not necessary.

Fire-Retardant Paint

Excessively thick coats of paint in the holds of battleships constitute a fire hazard when subjected to heat from burning magazines On the other hand, coats of normal thickness present no hazard, either on steel, plaster or wood However, in some cases, it is desirable to have a paint that insulates combustible structures from flame for a considerable time Studies indicate that compositions containing substantial amounts of phospate (52) or chlorinated paraffin (53) rank high in this property Laboratory testing of fire-retardant paint has always required tremendous numbers of hard-to-get wood panels The New York Production Club has devised a test that uses small panels and agrees very well with the modified Schlyter test

Painting Southern Yellow Pine

Satisfactory painting of southern yellow pine is still unsolved The problem is being studied in a broad way at the Georgia School of Technology (54). This program lays special emphasis on two-coat paint systems and includes several commercial two-coat and three-coat systems for comparison. In one series of primers, various ratios of zinc-sulfide, leaded-zinc-oxide extenders were used, in another, various ratios of titanium pigments and basic carbonate white lead extenders were used, in still other series various vehicles were used, mainly with 40 parts titanium-varium, 40 parts basic carbonate white lead, 10 parts diatomaceous silica and 10 parts asbestine The same top coat was used throughout In general, two-coat systems were only slightly, or not at all inferior, to three-coat systems Reasonable variations in type or content of pigment appears to have little influence on the results. Low varnish or bodied oil content seemed to be as effective as higher content Varnishes made with tung oil and dehydrated castor oil were superior to other oils About 275 primers were applied to four panels each.

This subject was further pursued in a round-table discussion (55) at a meeting of the Southern Paint and Varnish Production Club The solution of this problem is important, because approximately 66 per cent of our total softwood lumber supply includes southern yellow pine and Douglas fir It appears that further progress may come from wood treatment and changes in binders rather than from pigment formulations

Miscellaneous Coatings

Mercury compounds have not been used for their fungicidal properties in paints that are used where food is processed, because of possible harmful effects to humans. It is now reported that rabbits were not harmed by eating enamels that contained phenyl mercuric naphthenate (56) In a very comprehensive study, the fungicidal activity of 555 organic compounds belonging to 15 classes were evaluated (57). The activity of phenols and organo-mercurial was confirmed. In some cases, steric hindrance reduced activities of groups that have marked activities otherwise.

It wasn't long after the development of DDT that formulators began to consider its use in paint. Although tests demonstrated that this method of applying an insecticide works, the efficiency is low, because the greater portion of the insecticide is not available. The effectiveness of insecticidal paints must be tested biologically and with extreme care (58).

In the selection of extender pigments, the formulator must be guided by properties, such as wettability, particle size, and reactivity Wet ground calcites have been compared with several other types of extender pigments, including other calcium carbonates to show that they fulfill all extender pigment requirements for interior architectural paints (59) Extremely fine precipitated calcium carbonate is said to reduce the amount of hiding pigments needed in paint (60)

A new property, *saturation value*, is suggested as a useful tool in formulating paints (61) This is a function of the volume of pigment, total volume of binder in the paint, and volume of binder required to saturate the pigment Saturation value is closely related to enamel *hold out*, gloss and wet abrasion resistance

Moisture Impermeable Coatings

For atmospheric conditions existing in homes, the moisture permeability of the coating should not exceed 1 25 grains per sq ft per in of mercury pressure difference In many other places, such as vegetable storage warehouses, very high humidity is necessary (62) Practical tests indicate that two-coat and three-coat systems are available for these extreme conditions Most of the top coats in these tests contained some type of asphalt

Although many studies of water-permeability of films may be found in the literature, only one of these has recorded any measurements on rosin Films of rosin and metallic rosinates are brittle, but can be handled if deposited on thin paper (63) The electromagnetic microbalance designed by Stock can be used to measure the moisture (64) that passes through the films The effect of temperature on the diffusion process was derived mathematically (65)

Coatings for closures perform erratically over different metals unless a size coat is first applied to the metal The choice of size depends on both the top coat and the metal How to get about formulating the closures is shown by several examples (66)

Ready-mixed aluminum paint may be expected to displace the double container type to a great extent as a result of recent work (67) The most important precaution in maintaining the leafing is to keep the moisture content low,—under 0 1 per cent Excess water not only destroys leafing but also reacts with the aluminum to form hydrogen gas Lead and manganese driers must be avoided, cobalt in the form of naphthenates, octoates, or the like should be employed Increasing the specific gravity of the vehicle increases the leafing of the aluminum, while increasing the viscosity decreases the leafing. Thus, the greatest leafing is obtained with vehicles of high specific gravity and low viscosity (68)

Two new types of *bloom* are held to result from swelling characteristics of the film and the exudation of liquid materials from the gelled portion (35)

Bronzing of paints has been an elusive phenomenon but has now been run down—and measured with a spectrophotometer (36). One type arises from selective reflectance at an interface; another, from selective interference of light reflected from neighboring structures The hue of interface bronze remains fairly constant at different angles of view, that of interference bronze varies widely

Manufacturing

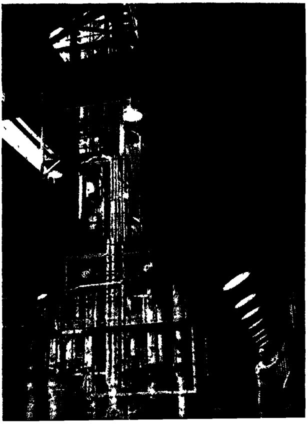
This industry intends to keep up-to-date in its processes and factory layout There is some indication that set kettles are more economical than portable ones for bodying oils and cooking alkyd varnishes (69) However, the small portable kettle is still necessary and is now available with many improvements Modern types have all the gadgets of the large set kettles A Dowtherm kettle provided with an integral electric heating unit has been investigated (70) One modern varnish plant (71) features ease of expanding production and convenient handling of materials An experimental model of a new colloid mill has been tested (72) Photographs of glass-end ball mills in operation show why the best speed is about 60 per cent of the critical At higher speeds the balls "open out" (73) and efficiency is lost. A new filter, known as the Forrest, appears to be very efficient (74) On certain types of enamels it has a capacity of over 1,000 gallons per hour.

Physical Testing

The well-known test for livering tendencies of vehicles that use zinc oxide as the reagent is shown to be unreliable (75) when other pigments are to be used in the vehicle Many technologists use the Hegman Gage to determine fineness of grind, but only recently has a cooperative study demonstrated its value (76) Longer channels and a knife edge scraper are recommended to improve the operation of the gage (77, 78)

A black and white chart with a gray scale on each is

Plant for the solvent fractionation of drying and semi-drying oils used in the paint and varnish industries.



proposed as a design for a hiding power chart (79) In another scheme for determining hiding power, the paint is applied to clear glass panels in different thicknesses The reflectances of the films over a black background or white background (depending on color of paint) are measured and the curves relating weight of paint to reflectance are plotted (80) To facilitate gloss measurements, standards for the low and medium range are recommended Also recommended are some changes in the aperture spread (81)

Determination of drying time continues to challenge the ingenuity of the technologists A proposed method for "dust free" time deposits a fixed amount of flock on the film at frequent intervals (82) Correlation with finger touch method is poor

Magnetic devices for measuring the thickness of films on iron have been in use for several years. Since aluminum is not magnetic, these devices are not suitable for films on it But by inductance measurements, the thickness of films on the light metals can be measured (83).

In a new abrasion tester (84), the test pieces are fastened to an endless belt Each piece in turn is brought into contact with a moving strip of sandpaper, so that new abrading surface is continually being used.

The routine laboratory determination of permeability has been speeded up by a new apparatus (85), that enables the weighing of the permeability cups without removal from the humidity chamber in which they are stored.

Immersing small pieces of metals in an aqueous suspension of a pigment has been one of the preliminary tests for rust-inhabitive properties. The hydrogen potential of a paint film measured against a calomel cell reveals the tendency of painted metal to corrode long before any corrosion is visible A negative potential indicates that corrosion is going on (86). Electrical resistance may also be used to indicate anticorrosive properties of a film (87) Good protection is obtained at resistance greater than log R = 8, poor protection at resistance less than log R = 6.

During the war the salt spray test was considered an important one for evaluating continuity of the films. However, distilled water forms blisters more rapidly than salt solution (88), because the osmotic pressure of salt solutions is higher than that of water absorbed by the film. An extensive symposium on immersion testing (89) considered such variables as type of steel, method of cleaning, criterion of cleanness, and edge protection Immersion tests have limited value because protection by the film decreases after a certain period (90). A relation between swelling of linseed stand oil films and their durability could not be established

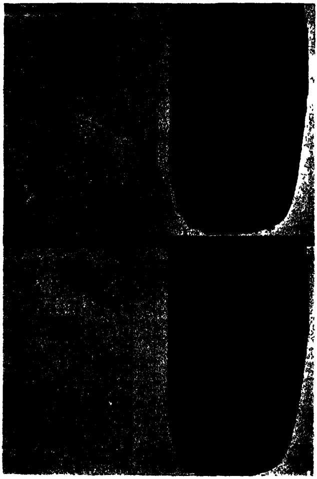
Individual operators are usually able to check themselves in oil absorption determinations but agreement between operators is another story. Agreement can be improved by several simple precautions (91).

The electron microscope came into wide use for many applications during the war. The technique of preparing samples of pigments and the limitations in interpreting the data have been outlined for the benefit of workers in this field (92).

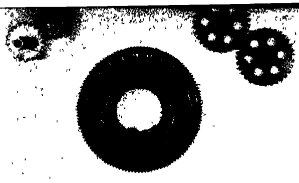
Chemical Analysis

A few advances in analytical methods have been made. The Karl Fischer method for water is adaptable for paints, except those containing zinc oxide (93). New recommendations for determining moisture in pigments feature drying under vacuum and over phosphorus pentoxide (94) at room temperature with and without previous heating. Higher but reproducible results are claimed

Chromium may be detected by a microchemical colorimetric test using strychnine in concentrated sulfuric acid (95) A purple violet color changing to red indicates chromate A colorimetric method for red lead works in the presence of all other known pigments (96) The determination of aluminum in aluminum pigment by its reducing action of ferric sulfate in a sulfuric acid solution (97) has been made practical If the organic matter of paints that contain mercury is destroyed by a mixture of fuming sulfuric and red fuming nitric acids, the thiocyanate method of titrating mercury can be used (98).

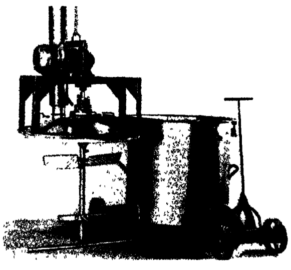


Protective effect of 1 per cent of copper phenolate in linseed oil film. Films of treated and untreated oil were flowed on glass plates and then exposed in an accelerated weathering machine. Dark films at left contain 1 per cent of copper phenolate. Upper row shows condition at end of 250 hours; lower at end of 500 hours. Same film. Note the sound condition of the treated film.



Coating of internal engine parts with resin finishes was adopted during war for protection under adverse conditions.

Filmmeter for determining thickness of paint or varnish films on non-magnetic materials, such as aluminum.



Portable kettle with stirrer and condenser for making varnish and synthetic resins.

Protective coating of phenolic finish applied to steel bridge prevents corrosion caused by river and traffic fumes.

If only 0.1 to 0.15 gram sample is taken, only 10 to 20 minutes of heating is needed for determination of the solids in resin solutions (99). The determination of the saponification value of natural waxes is made easier if an equal volume of carbitol is added to the alcoholic potassium hydroxide in the reaction flask (100). And a more adequate procedure for hexabromide is suggested (101).

Committee D-1 of the American Society for Testing Materials continues to grind out new and revised specifications and methods of test. At the annual meeting fifteen subcommittees made recommendations affecting 26 standards and methods (102). A survey of methods for testing resins will be useful to those who are working in this field (103).

Electrostatic Spraying and Detearing

An electrostatic field has been utilized in the finishing industry in two ways. In one, a high electrostatic charge is applied to the article being coated. The spray coming into the field has the opposite charge and is attracted to the article and deposited on it in a remarkably uniform thickness, on the far side as well as on the near side. In the second application, articles that have been coated by dipping are brought into an electrostatic field which attracts and removes the tears and fatty edges. The fire hazard connected with these processes is the possibility of electrical discharge in a spray booth where explosive vapors may be present. Recommendations for installations using electrostatic coating have been made by the NFPA (104).

Natural Resins

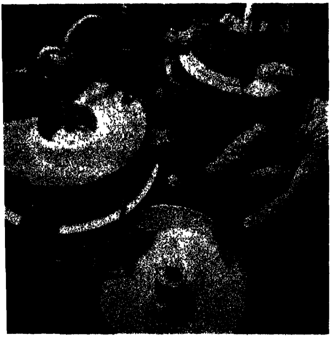
Interest in natural resins is not wholly dormant. Research at the American Gum Importers Association had to be given up during the war, but other organizations have carried on to some extent. This resulted in a treated Congo resin (treatment not disclosed) that may be used for spirit varnishes whose properties are intermediate between those made with hard Manila resin and those made with shellac (105). It may also be used as a reactive ingredient of alkyd resins. Some efforts to improve the usefulness of lac were not successful. The adhesion of ammoniacal solutions of lac could not be increased by addition of methyl cellulose or carboxyl methyl cellulose (106). Neither were attempts to esterify the 5-hydroxyl groups of lac with fatty acids any more successful. Dehydroxylation occurs and waxy products of no special merit for paints result (107).

Office of Technical Services

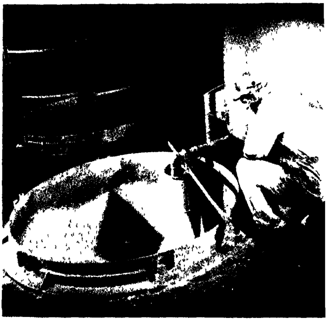
Several papers review the wartime experiences in painting (108, 109, 110). This review would not be complete without reference to collection of the reports of German industrial data collected by the scientific investigators after World War II. The Bibliography of Scientific and Industrial Reports contains abstracts of these reports. Besides the one dealing with Europe, the Bibliography contains many reports made by the United States Government Agencies and private concerns conducting research for the Government. The reports in the form of microfilm or photoprint may be obtained from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

Before being used in paints and coatings, drying oils are partly polymerized or "bodied" by heating in kettles.

The stone mill, one of the oldest methods for grinding and compounding paint ingredients, is still widely used.



Battery of modern five-roll mills operate continuously to mix pigments and oils to a smooth paste-like consistency.



After thinning and tinting, finished paint passes through a fine screen to the packaging machine feed-tank.

Illustrations for this chapter were obtained through the courtesy of M. W. Kellogg Co, Woburn Chemical Corp, E. I. du Pont de Nemours & Co, The Arco Co, National Paint, Varnish and Lacquer Association, Bureau of Aeronautics (U. S. Navy), American Instrument Co, Brighton Copper Works, Inc, American Iron and Steel Institute.

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CHAPTER XXI

PETROLEUM

by GUSTAV EGLOFF

The petroleum industry in mid-1947 may be said to have been still riding on a tidal wave of demands. The prognosticators foresaw a sharp drop in petroleum demands with the cessation of military requirements, but their predictions did not come to pass and all branches of the petroleum industry are utilizing every resource to supply an unprecedented market for all types of petroleum products.

The present situation strikes the refining division with particular force and much readjustment and planned expansion is taking place to keep the production of refined products in line with demands United States daily production of crude oil has increased steadily since the war. Crude production, daily runs to refinery stills, and total domestic demand for 1945, 1946 and parts of 1947 are given in Table I (1, 2)

During 1946, one of the major adjustments in refining practice was necessitated by the rapidly increasing demands for distillate fuels for household heating purposes, diesel engines, and catalytic cracking In order to satisfy these demands, more crude oil was processed, higher percentage yields of straight-run distillate fuels were produced from crude, and corresponding cracked distillates were blended with the straight-run products to make household heating oils. The increased production of distillate fuels accounted for slightly lower percentage yields of gasoline and residual fuel. By adjusting relative yields of different products, refiners prevented the building up of excess stocks of any single product, which attests to the flexibility of present refining operations (3).

The additional strain upon the refining industry is reflected in the progressive increases in total refinery capacities which have taken place since 1945 In that year the average daily charging capacity of all refinery stills for crude oils was 5,214,500 barrels. In 1946, this had increased to 5,432,000 barrels, 86.5 per cent of which was in actual operation (4, 5). In the middle of 1947, refinery capacity for crude oils was 5,611,000 barrels per day and 49 refiners replying to a survey indicated that new construction would increase crude oil capacities 307,000 barrels per day by 1949. Replacement of existing facilities to the extent of 100,000 barrels a day was contemplated (6) Estimates indicate that a billion dollars had been set aside for refinery expansion for the two years, 1947-1948

The capacity of the average U S. refinery is increasing year by year In 1940, the average capacity of 462 operating refineries was 9,600 barrels of crude oil daily. In 1945, 401 operating refineries had a daily average charging capacity of 13,000 barrels. In 1946 the average was 12,860 barrels and latest reports for 1947 showed 365 operating refineries averaging 13,907 barrels daily crude capacity. The largest U. S. refinery is that of the Gulf Refining Company at Port Arthur, Texas, which charges 192,000 barrels per day of crude oil. The plant of the Humble Oil and Refining Company at Baytown, Texas, is second with a capacity of 190,000 barrels a day and the Standard of New Jersey refinery at Baton Rouge is third with a capacity of 180,000 barrels a day.

The demands of a wartime economy imposed upon the petroleum refiner the need for manufacturing previously unheard of amounts of 100 octane and 100 plus octane aviation gasoline, hydrocarbon bases for the manufacture of synthetic rubber and toluene for TNT. These major demands stimulated the production of special hydrocarbons by synthetic processes which, though only known on a laboratory or pilot plant scale, were rapidly advanced to commercial status.

Aviation Gasoline

In the field of aviation fuel, the daily production at the time of Pearl Harbor was about 46,000 barrels a day. At the peak of wartime demand in 1945 over 500,000 barrels a day were supplied to the armed forces, more than a tenfold increase (7). The demand for combat aviation fuel suffered a precipitous decline after V-J Day and domestic demand for all grades of aviation fuel in 1946 was around 35,000 barrels a day, though this had increased to 70,000 barrels in July, 1947 (1)

During the war, the cry was continually for higher and higher octane number aviation gasoline ingredients and the rapid development of processes for high octane

TABLE I

Time	*Production*	*Run to Stills*	*Domestic Demands*
1945	4,687,900	4,711,000	4,843,000
1946	4,744,900	4,744,000	4,907,000
1947 January-August average	4,975,625	4,957,125	5,311,888
1947 week ending November 15	5,257,100	5,229,000	....

rating hydrocarbons has left a number of plants as carry over which require adaptation to the manufacture of ordinary motor gasoline if they are to continue to operate. Table II summarizes the refinery units that were involved in the production of high octane aviation gasoline during the war (7).

TABLE II

Type of Plant	*Number of Units*
Catalytic cracking	77
Alkylation	75
Isomerization	37
Hydrogenation	4
Dehydrogenation	2
Miscellaneous	16

Motor Fuel

The principal function of the petroleum refining industry is still to provide fuel for gasoline motors, diesel engines, household and industrial heating and railroad and marine use. The trend in gasoline demands is a good index of the growing demand for petroleum fuel. One of the most surprising developments in 1946 which still continued in 1947 was the heavy demand for gasoline. The demand persisted in spite of the relatively slow increase in the number of passenger cars, trucks and other vehicles powered by gasoline motors. The figures in Table III are indicative of gasoline demand (1,2). In 1946, there was a 5.5 per cent increase in gasoline demand, and in 1947 there was apparently, at the time of this writing, a 6.0 per cent increase over 1946

TABLE III
Gasoline Consumption
(in barrels)

	Per Year	*Per Day*
1945	696,407,000	1,908,000
1946	734,833,000	2,013,000
1947*	778,000,000	2,130,000

* Projected, based on January-August data.

Superfractionation

Superfractional distillation was employed during the war to segregate high octane rating fractions of primary straight-run gasolines for base stocks to be blended with hydrocarbon synthetics in aviation gasoline. Lower octane rating fractions obtained as by-products of this operation were blended with ordinary motor gasoline. The separation of high octane fractions by closely controlled distillation is not applicable to all crude oils. There is a strong probability that some superfractionators will be employed in plants manufacturing chemical derivatives (8).

Another use of simple fractional distillation in the production of higher octane rating gasoline has been *undercutting* or recovering lower end point straight-run gasolines than is usual. This, of course, reduces yields from crude and makes it necessary to reprocess the higher boiling gasoline fractions to improve their octane rating. The poor octane rating material, if not reprocessed, can be used in third grade gasoline. An example will show the effect of undercutting on octane rating. In one case a 270 deg. F. end point gasoline had 61 motor method octane number *clear* or unloaded and

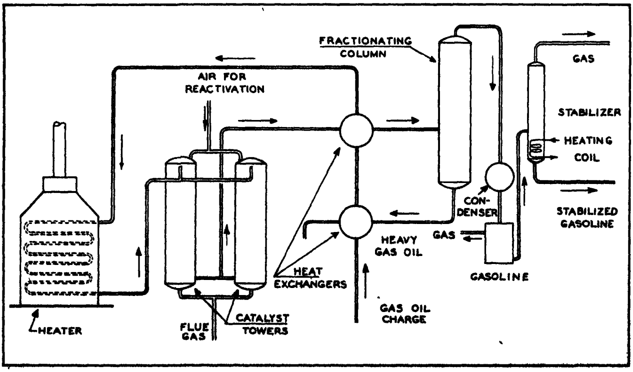


Fig. 1. Fixed bed catalytic cracking process (Houdry); catalyst beds are alternately used and reactivated.

81 octane number after the addition of 3 cc's of tetraethyl lead per gallon. A 400 deg F. end point material from the same crude oil had 50 octane number unleaded and 71 octane number after the addition of 3 cc's of tetraethyl lead (9).

Thermal Cracking

Thermal cracking continues to hold an important position in post-war petroleum refining. The great majority of plant installations, which had daily charging capacities of around two million barrels a day pre-war, are still operating.

The Pure Oil Company has improved the octane rating of its refinery gasoline by arranging the refinery flow so that crude oil from three combination units is distilled to 30 per cent residues which are cracked in a newly designed delayed coking unit The use of this expedient has increased motor fuel production from 52 5 per cent to 59 4 per cent and reduced the production of residual fuel oil from 27 66 to 17.2 per cent without changing the yields of other products The motor method octane rating of the refinery gasoline was four points higher as a result of the operating combination employed (10).

Catalytic Cracking

Catalytic cracking, a process which was undergoing a systematic and orderly development pre-war, made unusually rapid progress during the war period and is continuing to progress at the present time. The commercial development of this process has been fostered by the need for higher octane gasoline than is obtainable by thermal cracking The older thermal process yields gasoline having about 68 octane rating while catalytic cracking produces gasoline having from 80 to 82 motor method octane number Gasolines of 400 deg. F end point from catalytic cracking have motor method octane ratings around 80 and research ratings of about 90, which compare with values of 68 and 76, respectively, for thermally cracked gasolines of similar boiling range. A special advantage of catalytically cracked gasoline lies in the fact that the fractions boiling between 250 deg and 400 deg F and higher have octane ratings nearly as good as those of the fractions boiling below 250 deg F As a result, more of the higher boiling range components can be used, thus increasing yields without depreciating the octane rating of the gasoline as a whole (11, 23)

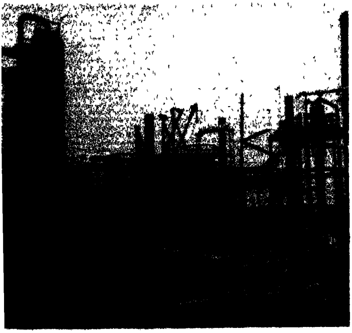


Fig 2. Houdry unit; cracked products from catalyst chambers (center) are fractionated (left).

During the war, catalytic cracking was employed to produce the base stocks for aviation gasoline blends which also contained synthetic hydrocarbons from alkylation and polymerization plants, isopentane boiling at about 100 deg F for vapor pressure and tetraethyl lead up to 4 6 cc's per gallon Such blends above one hundred in octane rating are graded in terms of performance rating as determined under actual flight conditions

The catalysts used in various catalytic cracking processes are generally activated clays of synthetically prepared silica-alumina or silica-magnesia composites The differences in catalytic cracking processes are basically in the way that they use the catalyst and its physical form.

Fixed Bed

In the earliest commercially installed Houdry process, small granules or pellets were used as filler in cracking chambers, and the vapors of gas oil distillates were cracked in contact with these catalyst beds until the gradual accumulation of carbonaceous deposits necessitated a shift to new or unregenerated catalysts while the deposits on the first bed were burned off by air. Problems of temperature control beset this type of process, both during the cracking period when it was necessary to add heat to maintain cracking temperatures, and during the regeneration period when heat was evolved and had to be dissipated in some way The problems of heat transfer have been solved by the use of molten salt mixtures that are circulated around banks of parallel catalyst tubes to absorb excess heat from the regeneration zone and convey it to the reaction zone.

Figure 1 shows the essential parts of the fixed bed catalytic cracking operation. A charge of intermediate boiling range distillate known as gas oil is introduced to the plant through two heat exchangers so that the heat in the bottoms from the plant fractionating column and the heat in the vapors from the catalyst towers are partly utilized to heat the charge which is then passed through a tubular heating element to complete its vaporization. Alternate catalyst towers are connected in parallel so that the oil can be passing through a fresh or regenerated bed of the catalyst while another bed is being reactivated. The cracked products pass through a fractionating system and are separated into gases, gasoline, and heavy gas oil that may be returned for further cracking with the fresh charge. Figure 2 shows such a fixed bed catalytic cracking plant (12).

Moving Bed

Another method of catalytic cracking operation is known as the Thermofor, or TCC, process. This can also be designated as the moving catalyst bed process. The catalyst is used in the form of small pellets or spheres. A line diagram indicating the general flow in this type of operation is shown in Figure 3, and a photograph of a commercial plant is shown in Figure 4 (13). Charging oil is pumped through a tubular heater and then into the bottom of a reactor, the heated vapors passing upwardly through the catalyst which slowly gravitates downwardly en masse. Alternatively the vapors can be introduced into the top of the reactor to flow concurrently with the catalyst. The catalyst level in the reactor is maintained by the introduction of regenerated material from a hopper placed above the reactor. The cracked products pass from the top of the reactor through a small trap to collect catalyst dust and the cracked oil vapors pass on to a distilling column from which gas and gasoline are recovered as well as heavy distillates suitable for furnace oil, diesel fuel, or cycle oil for further cracking.

The spent catalyst passes from the bottom of the reactor into an enclosed bucket type catalyst elevator which carries the catalyst to the top of the regenerator in which it passes downwardly as in the reactor counterflow to a stream of air or low oxygen content gases for burning off carbonaceous deposits. The decarbonized particles then flow from the bottom of the regenerator into another bucket elevator which conveys the catalyst particles back to the hopper above the reactor. In this way a continuous circulation of catalyst from reactor to regenerator and back is maintained.

Fluid Flow

The third, and most rapidly growing, catalytic cracking process is in the Fluid Flow type which utilizes the catalyst in an extremely fine state of subdivision. In the first plants using powdered catalyst, the oil vapors undergoing cracking carried the catalyst upwardly through the reactor and into cyclone separators from which the catalyst was sent to a regenerating zone and the cracked gases and vapors passed to a fractionating column The separated catalyst was fed into a stream of air or low oxygen flue gas which carried it through the regenerator to a hopper placed above the reactor. The latest development in Fluid catalytic cracking passes preheated oil vapors through a reactor containing a mass of catalyst which is maintained in a turbulent condition by the passage of the vapors, which carry only small amounts of the powdered catalyst out of the reactor. The spent catalyst overflows from the reactor at a fixed level, is stripped of oil by steam and passes into the regenerator where it is again kept turbulent by a stream of oxygen-containing gas passed through to burn off carbonaceous deposits In this latest and most important development of catalytic cracking, such small amounts of catalyst are carried out of the reactor and regenerator by the oil vapors and reactivating gases respectively that recovery equipment can frequently be entirely eliminated.

The general flow in a large scale fluid catalytic cracking plant is shown in Figure 5 (14). The oil

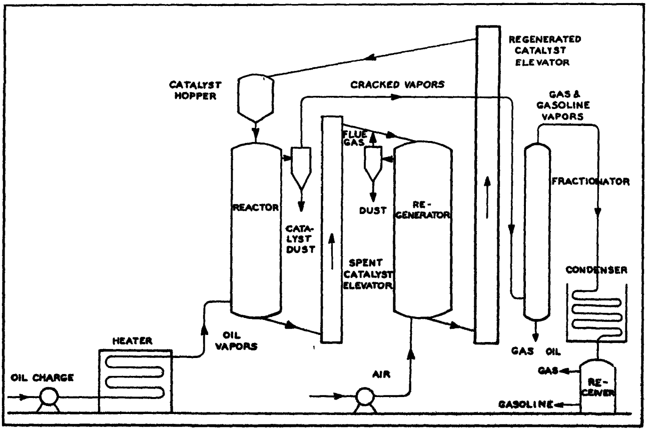


Fig. 3. Catalyst pellets pass continuously through the reactor and regenerator in moving bed process (TCC).

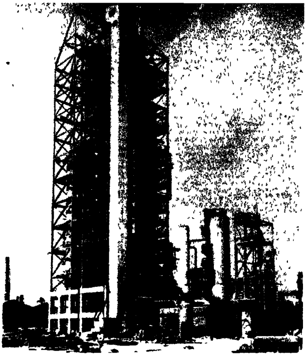


Fig. 4. Thermofor catalytic cracking unit: vaporized oil passes upward and countercurrent to catalyst flow.

vapors carry the catalyst passing out from the bottom of the regenerated catalyst standpipe into the reactor The spent catalyst, after being stripped of oil with steam, is elevated by a stream of air through the spent catalyst carrier line into the regenerator Electrical precipitators recover such fines as are carried out of the regenerator. Hoppers for spent and fresh catalyst are provided by means of maintaining catalyst supply for both reaction and regenerating zones Figure 6 is a photograph of the plant whose flowsheet is shown in Figure 5.

A large scale Fluid Flow unit is that of Shell Oil Company's refinery at Houston, Texas, which is designed to produce 12,500 barrels a day of high octane motor gasoline. This plant was the first to operate with micro-spherical catalyst. The feed to the plant is distillate gas oil from a West Texas crude. The overall height of the plant has been reduced by careful design of the catalyst circulation system. Two-stage cyclone separators are used for removing catalyst fines from hydrocarbon vapors leaving the reactors This eliminates a large proportion of extremely fine catalyst particles otherwise carried to the fractional distillation system and lowers the concentration of catalyst in the bottoms from the main fractionator (15).

In this plant, fresh oil and intermediate recycle oil are heated in a tubular heater to 800 deg. F. and partially vaporized. Before entering the reactor, the oil meets a stream of regenerated catalyst at 1050 deg. F. which completes its vaporization, the oil vapor and catalyst then entering the reactor at 900 deg. F. The bottom of the reactor is conical It contains a grid formed by box type girders containing venturi type openings for distributing catalyst and oil vapor throughout the reactor The faces of the openings in the beams are fitted with removable wear plates and erosion is minimized by the design of the orifices to promote smooth flow The highest velocity of the oil vapors and catalyst is low enough to permit formation of a dense phase bed of catalyst in the lower portion of the reactor

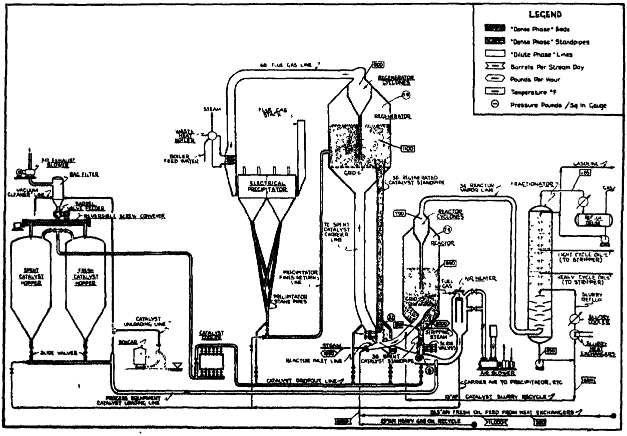


Fig. 5. Fluid catalytic cracking process uses powdered catalyst maintained in turbulent condition.

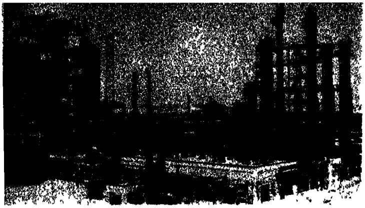


Fig 8. Fluid catalyst cracking plant: this process is the most widely used and most rapidly growing.

Spent catalyst from the reactor is carried by air under 18 lbs pressure through a riser 5 ft in diameter A dense phase bed of catalyst is formed in the regenerator as in the reactor. The regenerator also contains a distributing grid similar to that of the reactor. Regenerated catalyst overflows at a level below the distributing grids. The regenerator is completely lined with 4 in. of block insulation and 3 in. of fire brick so that the external temperature of the shale is maintained at 135 to 150 deg. F. in spite of the internal temperature of 1050 deg. F.

The heat evolved in the regenerator is used in waste heat boilers and the steam generated is sufficient to furnish all process requirements and leave some for general refinery use The total steam amounts to 175,000 lbs per hour, 115,000 lbs of which are in excess of plant requirements and supplied for use elsewhere in the refinery. The steam is superheated by a radiant heater to 550 deg F

In the regenerator the catalyst overflow is controlled by two slide valves which are activated by variations in the catalyst bed temperature The catalyst is circulated through interior pipe coils and back to a point below the distribution grid (16).

Universal Oil Products Company installed a Fluid catalytic cracking unit for the Aurora Gasoline Company of Detroit, Michigan, that went on stream June 19, 1947 (17). The line diaphragm in Figure 7 shows the flow in this plant and Figure 8 is a photograph that clearly indicates the compact character of the equip-

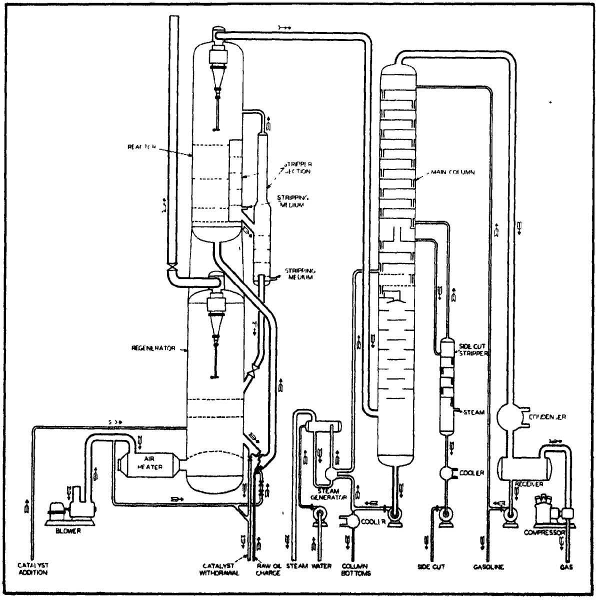


Fig 7. One type of fluid catalytic cracker utilizes a special arrangement of reactor and regenerator.

ment. Numerous improved features are included in this plant that was designed for charging 4,000 barrels per day of gas oil. It was the first small plant to use microspherical catalyst and also the first to have grid plates in the catalyst zone to improve contact between oil and catalyst and to increase gasoline yields

From the inception of its operation through November, 1947, it had charged from 3,500 to 4,000 barrels a day of gas oil and produced 42 per cent of gasoline having octane ratings from 78 to 80 motor method and 90 to 92 research method. The gas oil charged, which is made in a vacuum still, is the production from 12,000 barrels a day of mixed crudes from Texas, Wyoming, Illinois and Michigan. The gas oil charge is preheated by heat exchange with fractionator bottoms and vaporized by hot catalyst as both enter the reactor

By having the reactor above the regenerator, spent catalyst overflows directly from the reactor, which eliminates the formerly used air riser which customarily operated hot and required large expansion joints. The regenerator is operated under a pressure of 15-19 lbs per sq in gauge which reduces its size and also the size of the pipes supplying air to it

The Texas Company has constructed a Fluid catalytic cracking unit at its Casper, Wyoming, refinery which is designed to charge 4,000 barrels a day of gas oil produced from 10,000 barrels a day of Cody crude (18) The gas oil is of high sulphur content which has necessitated the use of considerable alloy steel in the construction of the plant. One feature of the unit is designated as *balanced pressure*. Both reactor and regenerator are supported at the same level which has permitted reducing the height of equipment and the standpipes. In the electrical precipitators used for recovering catalyst fines, more than ordinary pressure is used which increases the efficiency of the catalyst recovery.

Among the larger units Standard Oil Company of Indiana had under construction in 1946 were three 25,000 barrel a day plants for the Fluid catalytic cracking of gas oil One of these started operating early in 1947, and another was on stream before the year ended. These plants are to incorporate the most recent developments in this process. The weight ratio of catalyst to oil in the reactor will be 6 8:1. Temperatures in the regenerator will be maintained at 1025 deg. F. by circulation of cold catalysts (19).

The Fluid catalytic cracking unit at the Avon, California refinery of the Tidewater Associated Oil Company has been operating post-war on a charging oil consisting of heavy California wax distillate. This oil averages 22 to 23 API gravity and has relatively high viscosity. The shift to this heavier charging oil was made gradually from straight run gas oil of 30 API or higher gravity during a continuous run of 415 days when operations were suspended for inspection and repairs, and not because of operating difficulties. The present charging oil is made by vacuum flashing of heavy crude oil residuum. The catalyst now in use consists of a small amount of synthetic catalyst used in wartime and a relatively large amount of added natural clay catalyst (20).

In view of the increasing importance of the Fluid catalytic cracking process, which has shown flexibility, dependability and economy in all installations, it has received considerable study for further improving its operation (21).

The Fluid catalytic cracking process embodies the following operating characteristics. (a) Flexibility; (b) Recycle of gas oil intermediates, (c) Low catalyst-to-oil ratio, (d) Efficient catalyst recovery, (e) Effective oil stripping from spent catalyst, (f) Both feed preheating and catalyst cooling

In flexibility, a unit is able to process charging stocks ranging from light gas oil to reduced crudes at their optimum cracking condition

For maximum economic yield of gasoline from a limited quantity of fresh gas oil, it seems advisable to hold the conversion to 50 per cent pass, and re-cycle unconverted oil to the extent of 30-50 per cent of the fresh feed While the maximum economic yield corresponds to about 70-75 per cent conversion to gas and gasoline, high carbon and gas yields and low liquid recovery are encountered if this is effected in single pass operation.

The amount of regenerated catalyst that can be profitably employed as a heat carrier is considerably above the minimum catalyst-to-oil ratio for optimum catalytic effect Incomplete removal of absorbed hydrocarbon from spent catalyst accounts for the major portions of

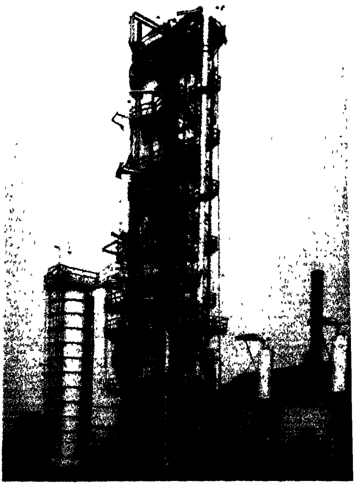


Fig 8. 4,000 bbl. per day U.O.P. fluid catalyst cracker shown diagramatically in Fig. 7

carbon and hydrogen in the catalyst deposits. Poor stripping of spent catalyst may increase the load on the regenerator by as much as 15 per cent. General trends favor low rather than high catalysts-to-oil ratios ranging between 5:1 minimum and 10·1 maximum. With high catalyst circulating rates there is increased production of catalyst fines lost from the system and deactivation of the catalyst because of repeated contacts with steam in the spent catalyst strippers Increased temperature differential between hot reactivated catalyst and oil feed increases carbon formation in the film of hydrocarbon which initially envelops the hot catalyst particles.

It is generally preferable to permit a small catalyst loss so that replacements will act to maintain the level of catalyst activity. A certain percentage of fines in the circulating system assures smooth and surge free operation

Means for preheating oil feed and for cooling the catalyst increases flexibility so that the heat balances in the regenerator and reactor can be maintained independent of each other Apparently the best temperature for preheating feed is 700 deg F

A great deal of plant experimentation has been conducted to determine the best conditions for regenerating catalyst activity (21A). The spent catalyst generally contains from 1 to 2 per cent by weight of carbonaceous deposits and for burning this off effectively, close control of operation is essential. The principal factors involved in catalyst reactivation are·

(a) Temperature, (b) Pressure, (c) Type of catalyst; (d) Composition of the deposit; (e) The proportion of deposit removed by oxidation, (f) The efficiency of contact of regenerating gas and catalyst.

In practically all commercial installations, regeneration temperatures between 1000 and 1200 deg F. are used and in the majority of cases, the temperature will be between 1025 and 1100 deg. F. Although combustion proceeds more rapidly at higher temperatures, this tends to deactivate the catalyst and raises costs because of excessive wear on equipment.

Some types of catalyst are more heat resistant than others and the type of catalyst also affects air requirements. The ratio of carbon dioxide to carbon monoxide in regenerator outlet gases may vary from 50:50 to 65:35, according to the type of catalyst being regenerated. Iron contamination seems to increase the ratio and result in increased air requirements. The composition of the catalyst deposit has a pronounced effect on the air requirements. The deposit contains not only carbon, but also hydrogen and sulphur and four times as much air is needed for burning a pound of hydrogen as is needed for a pound of carbon. High hydrogen content is the result of inadequate oil removal from the catalyst with steam, since the oil has a higher hydrogen content than the normal carbonaceous deposit.

The amount of deposit on a spent catalyst depends partly on the catalyst-oil ratio used in the cracking zone. The difficulty of carbon removal increases as the content decreases. Regenerated catalysts may contain from 0 3 to 1 0 per cent of deposit, but, as a general rule, it is being held between 0.3 and 0.7 per cent.

Good distribution of air through the spent catalyst bed is important. If the catalyst bed is too shallow, there is a tendency for channeling to occur and experience indicates that beds should be at least 10 ft and preferably 15 ft deep. The lineal gas velocity in the regenerator should be about 1.5 ft per second to minimize catalyst entrainment. Regenerator outlet pressures from 1 to 9 lbs are being used. While combustion takes place more rapidly at higher pressures and permits a reduction in the size of the regenerator, some of these advantages are offset by the cost of furnishing air at higher pressure

The yields of gasoline from the catalytic cracking of gas oil are from 45 to 50 per cent in once through operation without recycling of intermediate fractions. By converting all the olefins in the gaseous products to gasoline by catalytic polymerization, yields can be increased from 55 to 65 per cent and by using both recycling and polymerization, yields of gasoline of over 70 per cent are obtained

The catalytic cracking process uses somewhat lower temperatures and much lower pressures than thermal cracking processes. Pressures are used that are sufficient to insure flow The process has greater flexibility and can more easily vary the proportional yields and quality of both its gaseous and liquid products The use of catalysts in cracking decreases the tendency of polymerization to tars and increases the tendency toward formation of aromatics and isoparaffins in the gasoline. The olefinic content of catalytically cracking gasolines is somewhat lower than that of gasolines from thermal cracking As a result of decreased polymerization a minimum of residual fuel oil is formed and the aromatics and isoparaffins contribute to making a higher octane number gasoline The effect of catalyst in minimizing tar formation permits the use of higher boiling charging stocks with small coke production.

An important development in the two main catalytic processes is the use of spherical catalyst particles as beads in the Thermofor process and as microspheres in the Fluid process. These particles are made by dropping an unstable colloidal solution of a silica-alumina composite through oil and permitting it to set to a solid as beads. The formed globules are then washed, dried and calcined to make the final catalyst particles (22). The advantages in the use of spherical particles as compared with pellets or granulated powders is that, having no sharp edges, they are less subject to abrasion and less likely to erode mechanical equipment through which they pass.

Fluid flow catalytic cracking units are in commercial operation which have charging capacities varying from 2,500 to 25,000 barrels a day and one unit is being designed to process 42,000 barrels a day (23).

In one type of catalytic cracking operation, known as the Suspensoid process, a small amount of powdered clay catalyst is suspended in the oil entering the heating element of a tubular heater and reaction chamber cracking plant (24). This process is operated by the Imperial Oil Company of Canada, at its Sarnia, Ontario, refinery. Spent Filtrol clay from lubricating oil treatment is used as the catalyst The amount of catalyst used is small, usually less than five lbs per barrel of oil charged and by using these small quantities of the spent material from lubricating oil treatment, the catalyst can be discarded after once through operation, which eliminates the need for a catalyst regenerator In this process, best results are obtained when temperatures are increased and pressure reduced sufficiently to insure complete vaporization of the oil at the exit of the heating coil The process is operated so that conversions per pass are of the order of 80 to 90 per cent At such high conversions the quantity of recycle oil is small and the total heat load on the furnace is said to be less in comparison with strictly thermal operations

After cooling to about 500 deg. F, catalyst is removed from the cracked fuel oil residium by means of a rotary filter This filtered oil is of high quality since salts and carbonaceous matters are removed along with the clay

The Suspensoid process improves thermal cracking by utilizing existing equipment at a cost less than that of the Fluid or the Thermofor process The octane numbers of gasoline from Suspensoid cracking are 7 to 8 points higher by the motor method than gasoline produced in the same yield by thermal cracking, and 11 to 12 points higher by the research method The lead susceptibility is slightly less than that of gasolines from thermal cracking, but better than that of the gasoline from Fluid catalytic cracking It is also claimed that less fuel oil and more gas is produced in Suspensoid than in thermal cracking.

Additional costs above thermal cracking are reported to be less than 12 cents (U S. cy) per barrel of fresh feed and the reduction in lead requirements for a given octane rating is said to more than compensate for this increased cost.

During the war, the daily charging capacities of catalytic cracking plants were increased to 1,045,000 barrels a day. Post-war plants both large and small are being designed and constructed at a rapid rate Additions to Fluid catalytic cracking plants in the project, design or construction stage, are of the order of 200,000 barrels a day charging capacity, and when these are in operation, Fluid plants will represent about 60 per cent of all catalytic cracking plants (25)

The tonnage of catalyst now employed in catalytic cracking processes is literally enormous It has been estimated that there is a daily consumption of 200 tons of catalyst in all types of catalytic cracking processes now in operation in the United States. This may exceed the catalyst consumption in all other chemical processes (26).

The modernized post-war refinery contains a catalytic cracking plant and sufficient catalytic polymerization units for converting all 3 and 4 carbon olefins from both thermal and catalytic cracking operations into polymer gasoline.

Reforming

While catalytic cracking is supplanting many older processes employed to improve the octane rating of refinery gasolines, there is still activity in reforming processes of various types These processes include thermal reforming, and catalytic reforming, using several types of catalyst The processes which are intended for use on straight run gasoline will still be valuable when catalytic cracking is eventually installed while those that are employed for improving the octane rating of thermally cracked gasolines may be considered merely as temporary expedients (9).

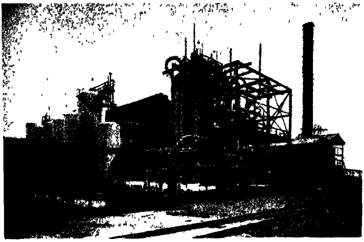
Thermal reforming processes which are employed principally to improve the octane rating of 250 to 400 deg F primary straight run naphthas are still showing utility when employed in conjunction with catalytic cracking. Thus a thermally cracked or thermally reformed gasoline of sufficiently high octane number can be improved materially by subjecting it to the Isoforming process in which the vapors of thermally cracked gasolines are contacted with cracking catalysts, usually in a fixed bed, at customary cracking temperatures, and pressures of from 5 to 20 lbs The main reaction in this conversion process is the isomerization of olefins to compounds of higher octane rating Liquid yields are as high as 99 per cent, and for the small loss, octane rating increases of 4 to 5 points are frequently obtainable The degree of improvement is a function of the initial olefin content and octane number of the thermally cracked material processed (9)

Hydroforming

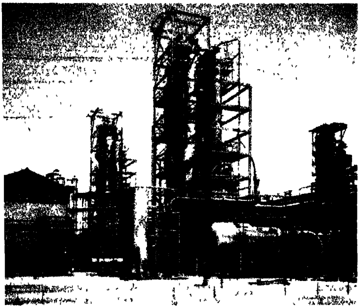
The hydroforming process in which straight run gasolines and naphthas are catalytically reformed in the presence of relatively high concentrations of hydrogen was originally developed for improving octane ratings (27, 28) The first hydroforming unit started operating in 1940, since then a total of 8 commercial units have been installed Hydroforming's wartime function was to produce toluene from selected naphtha fractions containing high percentages of methylcyclohexane, the corresponding cycloparaffin Its present post-war function is to improve octane ratings of naphthas and in the case of Standard Oil Company of California, to produce orthoxylene for its phthalic anhydride plant.

Toluene produced by the petroleum industry for the manufacture of TNT reached a figure of 270,000,000 gal per year, approximately 9 times that produced as a by-product of the coal carbonization industry. This enormous production was made possible by the adaption of the hydroforming process to toluene manufacture With greatly reduced demands for toluene postwar, hydroforming has returned to its primary objective of making high octane number blending hydrocarbons for motor gasolines.

In the hydroforming process, a charging stock of gasoline boiling range is passed, at about 1,000 deg. F. under 200 lbs per sq. in. gauge pressure, over a catalyst consisting of alumina and molybdena. Product gases are recycled so that the reforming reactions occur in the presence of a gas consisting or from 60 to 80 per cent hydrogen. The principal reaction involved in this process is the dehydrogenation of naphthanes. However, some of the non-aromatic hydrocarbons are cracked to lower boiling compounds and some alkyla-



Modern lubricating oil plants such as this one remove wax by solvent extraction.



Propane is cracked in this plant to produce ethylene, widely used in the petrochemical industry.

Polyforming unit produces high yields of gasoline from special types of feedstocks.

tion occurs since there is considerable formation of xylenes from charging stocks containing principally methylcyclohexane. Sulphur contained in the naphtha feed is 90 per cent removed by this process and many olefins are converted to paraffins or ring compounds (27, 28).

In converting the hydroforming process to peacetime operation for the production of a high octane aviation gasoline stock, practically the only change was the use of a wider boiling range feed. In reforming naphtha, the process yields from 78 to 80 per cent by volume of 80 motor method octane number gasoline. The remaining 20 to 22 per cent is about three-quarters dry gas and one-quarter heavy polymers and carbon.

The alumina-molybdena catalyst used in the hydroforming process by the Standard Oil Company of California is made by a co-precipitation process. This catalyst is claimed to be 50 per cent more active than catalysts made by impregnating alumina with molybdenum compounds and calcining to develop molybdenum oxide. At the close of the war, 75 per cent of catalytic reforming plants in the United States were using the co-precipitated catalyst In normal operation, the catalyst is regenerated after from 4 to 8 hours service by using air diluted with recirculated flue gas Temperatures are kept below a maximum of 1,100 deg. F. to avoid depreciating catalyst activity (27).

Cycloversion

Another reforming process in use at the present time is cycloversion, in which vapors of gasolines or naphthas are contacted with bauxite catalyst in fixed beds These catalytic reactors are added to ordinary thermal cracking or reforming plants (29). This is done by filling reaction chambers with bauxite catalyst or adding similarly filled chambers if necessary.

The catalyst readily decomposes sulphur compounds at temperatures between 700 and 800 deg F. Alkyl sulphides, alkyl disulphides and mercaptans are decomposed to hydrogen sulphide, but thiophenes are not greatly affected. In desulphurizing straight run gasolines very little change in the hydrocarbon composition is experienced. The resulphurization process can be applied to both straight run distillates and blends of straight run or cracked stocks. As catalyst activity declines due to build up of carbon on its surfaces, the reactor temperatures are increased. A characteristic increase would be from 725 to 790 deg. F., measured at the outlet of the reactor.

By using higher temperatures of 1,000 to 1,050 deg. F., the bauxite catalyst reforms straight run and cracked stocks with considerable improvement in octane ratings. Desulphurizing markedly improves the lead susceptibility of gasolines and naphhtas and reforming at higher temperatures further increases their octane numbers. It is claimed that the cycloversion process has advantages for small refiners who are not able financially to install catalytic cracking.

Polyforming

In the polyforming process, reforming and cracking are conducted in the presence of relatively large amounts of olefin containing cracked gases; originally 40 to 75 volumes of liquefied gases per 100 volumes of oil were used The more recent developments in this process employ increased amounts of cracked gases in the order of 150 to 300 volumes of liquefied gas per 100 volumes of the oil cracked (30) The gases may be those made by cracking the oil itself or may include those obtained from outside sources The use of greater amounts of gases is said to permit more severe cracking so that improved yields of gasoline of high anti-knock quality and sensitivity are obtained

Using the large excess of gases certain addition type reactions apparently take place between the gas and the products made by cracking the oil, and there is a reduced formation of coke The new development in polyforming is applicable to the conversion of refractory catalytically cracked gas oils to gasoline to improve the overall yields

With the higher liquefied gas dilutions, outlet temperatures of 1,025 to 1,100 deg F, and pressures from 1,000 to 2,000 lbs per sq in are used In single pass operation, conversions to gasoline and gases are usually between 60 and 70 per cent. Stabilized gasoline, gas oil, low API gravity fuel oil and a gas containing ethane and lighter hydrocarbons are obtained The cracked gas oil boiling between 400 and 600 deg F is generally a very exhausted stock that can produce only a little gasoline on further cracking It is said that the recycle stocks from high gas dilution polyforming of paraffinic gas oils are similar to those from catalytic cracking The quality of the cycle stocks depends on the character of the oil charged and the severity of cracking conditions The process can be operated for maximum butane-butenes It produces yields of gasoline of the same order as those that are obtained in catalytic cracking, the gasoline having numbers from 71 to 76 by the motor method

Polymerization

Since the war the polymerization plants that operated at reduced temperatures and throughputs to produce codimer for hydrogenation to aviation fuel by the selective polymerization of butylenes, have resumed their original function of non-selective operation to produce motor fuel polymers from both propylene and butylenes. Similarly, polymerization plants that were used to make cumene by alkylating benzene with propylene have given up this operation and gone back to making non-selective polymers for blending with cracked gasolines (9).

The commercial catalysts used in manufacturing motor fuel polymers are still either solid phosphoric acid or copper phosphate composites. Solid phosphoric acid catalyst produces gasoline having 80 to 82 motor method octane rating and a research rating of about 93 The process converts up to 95 per cent of the propylene and butylenes in cracked gases to gasoline (23) Complete conversion of three and four carbon atom olefins to relatively low vapor pressure polymer necessitates the use of outside butanes in many cases to produce gasoline with correct vapor pressures (10).

Alkylation

The post-war status of isobutane alkylation processes for the manufacture of high octane alkylates has depended largely on competitive factors and general economics (31) While new construction of isobutane alkylation plants is not proceeding at the present time, a large number of wartime alkylation plants are continuing to operate Plants that are still operating using sulphuric acid catalyst are those of the Standard of New Jersey, Standard of Indiana, Atlantic Refining Company, and other large companies Among the operating plants using hydrogen fluoride catalyst are those of the Sun Oil Company (8), the Standard of California, the Continental Oil Company, the Philips Petroleum Corporation and the Sinclair Company Present operation of alkylation plants is in the direction of larger throughputs and alkylates of slightly reduced octane rating since alkylate production now goes partly into motor fuels where it was blended in aviation fuel during the war

The situation in butane isomerization plants makes their operation in 1947 distinctly marginal At present, all butane isomerization processes require relatively pure charging stocks (7) A number of the butane isomerization units that operated during the war have been converted into polymerization plants (32, 33)

Octane Ratings

With the carryover of processes for making high octane products and the backlog of experience held by a majority of refiners, the oil industry is at present well able to supply gasolines that do not knock in engines of much higher compression ratios than the best in cars coming from today's production lines Besides higher compression ratios, the automotive industry is installing or considering the installation of many mechanical improvements that will have a far-reaching influence on automotive engine operation and fuel efficiency (23)

Octane ratings of both premium and regular priced gasolines began a sharp post-war rise that reached a maximum in the winter of 1945-46, the motor method octane number of the premium fuels attaining an average value of 80.9 and regular fuel a value of 75.9 However, this rise was halted during the winter of 1946-47 by a shortage of lead and difficulties in obtaining materials for the construction of gasoline manufacturing units During the winter of 1946-7, the motor method octane number of premium gasoline had fallen to 78 5 while regular gasoline was 75, the regular grade exhibiting a smaller loss than the premium fuel. In 1947, the situation as regards supplies of lead showed signs of improvement and the octane numbers of both premium and regular gasolines have resumed their rise, though the average values are still somewhat short of the previous maxima (34). The pre-war demand for premium gasoline was about 10 per cent of the total and reached a value of about 40 per cent toward the end of the war. It is now in the neighborhood of 30 per cent.

As indicative of the trend in automotive engines, the General Motors Corporation built a six cylinder engine with a compression ratio of 12.5 to 1 and installed it in a car for testing (35). Using a non-knocking fuel mixture of triptane and isooctane, an increase of 43 per cent in mileage per gallon of fuel was obtained at a car speed of 40 miles per hour It seems quite possible that the 1950 stock automobile engines will have compression ratios of 8.5 to 1 with corresponding economy in fuel consumption over present engines with compression ratios averaging 6.5 to 1.

Treating

In the treating field, most refiners are critically reviewing their processes In the conditioning of gasolines from both thermal and catalytic cracking, the use of processes for mercaptan removal, such as the Unisol, employing a solution of caustic soda in methanol, continues to grow with a corresponding decrease in the use of sweetening processes which basically convert mercaptans to alkyl disulphides which remain in the oil. The Solutizer process using a solution of petroleum-derived phenols in caustic soda for mercaptan extraction is used in present commercial units.

In sweetening processes where aqueous solutions are employed, such as the Doctor process, using sodium plumbite and sulphur, some developments have occurred in new compounds for breaking emulsions. These include such compounds as sodium stearate, oleate and abietate, as well as certain reagents of the Tretolite type (37).

Distillate Fuels

The post-war demands for distillate fuels, particularly home heating oil, have been higher than anticipated and operations in refineries have been reorganized to produce proportionately less gasoline and more of intermediate distillate products. This has involved running greater amounts of crude oil. Household heating oil now contains a considerable percentage of cycle stocks from catalytic and thermal cracking processes. These have slightly higher carbon content and require some burner modifications for their most efficient use (23). Total production of diesel fuel oil in 1946 was 288,445,000 barrels as against 249,224,000 in 1945, an increase of 15.7 per cent (3) In 1946 the current demand for locomotive Diesel fuels was five to six times greater than pre-war. About 10 per cent of large ships built in 1946 and 95 per cent of new orders for railroad engines specified diesel engines (23).

Lubricating Oils

During the war, practically no new lubricating oil plants were installed because the demands could be met with existing facilities. The developments which have raised the requirements of lubricating oils have been higher compression ratio automobiles, diesel engines, and higher speed machines (38). The production of lubricating oils continues to increase. In 1945 the production in the United States was 41,867,000 barrels; while in 1946 it had risen to 45,912,000 barrels—an increase of 9.7 per cent (3).

The older plants for acid-testing lubricating oils are rapidly becoming obsolete and are being superseded by plants for solvent extraction. The most common solvents employed are phenol, furfural, and Duosol, a propane-phenol-cresol mixture. A recent, private survey indicated that a total of 30,000 barrels a day of new lubricating oil treating capacity was installed in 1947, 18,000 of which are for solvent extraction processes to replace older plants Thus, a net increase of approximately 10 per cent or 12,000 barrels is to be added to the present United States capacity of 120,000 barrels a day (39).

Solvent extraction plants now have daily charging capacities of 109,770 barrels. That of furfural processes total 26,160 barrels, phenol 33,450, Duosol 31,000, sulphur dioxide-benzol 10,300 barrels. The only new plants which are being constructed are 7 using the furfural process and 7 using phenol, indicating the preference of refiners for these two types of processes, which now have over one-half the capacity of all solvent extraction plants. The Duosol process which uses propane-cresylic acid combines propane deasphalting and solvent refining in the same process.

Liquid propane is used in practically every lubricating oil plant as a selective solvent for deasphalting and dewaxing. By employing fractionating columns in propane deasphalting, the need for vacuum distillation is eliminated and the possibility of cracking in distilling lubricating oil stocks is minimized (38). The propane deasphalting plants of nine companies have a daily capacity of 20,000 barrels and still more of undesignated capacity are under construction for 8 other oil companies. The more recent plants are utilizing counter-current treating towers similar to those used in solvent refining processes instead of the older tank-type settlers.

In preparing lubricating oil stocks, the common method is to produce several narrow distillate cuts and process them separately. The finished oils are then blended to produce products of desired characteristics. Most lubricating oil plants are designed for the production of 95 viscosity index and 0 deg. F. pourpoint oils. 15 refiners are installing modern lubricating oil processes at 10 places in the United States, and 5 foreign localities. Most of these include vacuum distillation and propane deasphalting for preparing raw lubricating oil stocks. These oils are refined with single solvents such as furfural or phenol and then subjected to solvent dewaxing to obtain pourpoint. The finishing of the oils is being done either by clay contacting or percolation.

For dewaxing lubricating stocks, the two principal processes are the MEK (methylethylketone)-benzol and the propane process. The daily charging capacity of the MEK-benzol process installations is 45,300 barrels and that of the propane dewaxing plants 13,300 barrels daily. The sulphur dioxide-benzol plants have a total capacity of 2,400 barrels and the *Barisol* process, 4,700 barrels. Twelve companies at home and abroad are installing the MEK-benzol process and three companies, including one in Venezuela, are constructing propane dewaxing plants (38).

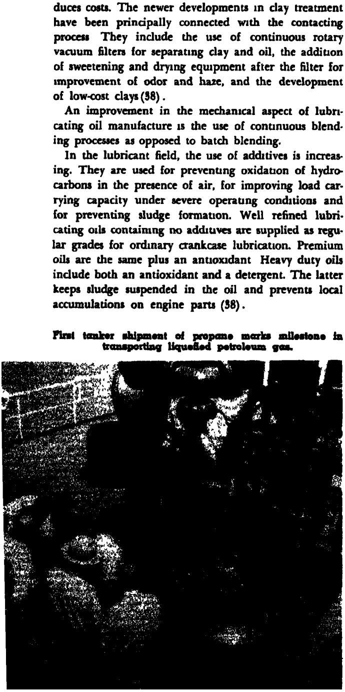
The production of both crystalline and microcrystalline waxes was stimulated by the war which found many new uses for wax. Peacetime demands have exceeded those of the war, and there is, at present, a shortage of wax. Almost all of the new microcrystalline waxes are made by solvent extraction processes whereas these waxes were first made by centrifuging heavy lubricating oil stocks (38).

There are still two major clay processes used in treating lubricating oils. In the *Contact* process, a finely divided clay is added to hot oil, stirred vigorously and then filtered through a rotary filter. In the percolation method the moderately warm lubricating oil stock is filtered through a bed of relatively coarse fullers earth Comparing the contact clay finishing process with the percolation method, the former has lower investment and higher operating costs while the latter has higher investment and lower operating costs. The contact process is now operated continuously with fresh clay added and spent clay discarded at all times. There is a steady production of oil of uniform quality In contrast, the percolation process is a batch operation and has the disadvantage that the quality of the filter effluent varies during the life of the clay; however, the granular clay can be reactivated and reused, which reduces costs. The newer developments in clay treatment have been principally connected with the contacting process They include the use of continuous rotary vacuum filters for separating clay and oil, the addition of sweetening and drying equipment after the filter for improvement of odor and haze, and the development of low-cost clays (38).

An improvement in the mechanical aspect of lubricating oil manufacture is the use of continuous blending processes as opposed to batch blending.

In the lubricant field, the use of additives is increasing. They are used for preventing oxidation of hydrocarbons in the presence of air, for improving load carrying capacity under severe operating conditions and for preventing sludge formation. Well refined lubricating oils containing no additives are supplied as regular grades for ordinary crankcase lubrication. Premium oils are the same plus an antioxidant Heavy duty oils include both an antioxidant and a detergent. The latter keeps sludge suspended in the oil and prevents local accumulations on engine parts (38).

First tanker shipment of propane marks milestone in transporting liquefied petroleum gas.



At present the production of synthetic lubricants by polymerizing ethylene or isobutylene is of a limited order These oils range in viscosity from 45 to 105 seconds Saybolt, at 210 deg. F. They have viscosity indices of at least 140 and carbon residues below 0.01 per cent, however, their manufacturing costs are high and their use is restricted to special markets (38).

Rubber

The production of synthetic rubbers of all types was about 820,000 tons in 1945. Petroleum was the major source of this production (40). The principal hydrocarbons furnished by the petroleum industry for rubber manufacture were butadiene, styrene and isobutylene. The first two hydrocarbons are the components of GRS rubber for tires and the third is the major constituent of Butyl rubber for making inner tubes.

Plants in which Butyl rubber is made by copolymerizing isobutylene and a small amount of isoprene are in full operation due to the increasing demand for Butyl rubber for inner tubes that retain air pressure ten to twenty times better than those made of natural rubber In this polymerization process, temperatures of minus 150 deg. F. are employed, and a boron fluoride catalyst is used.

Chemicals

In the manufacture of chemicals from petroleum, the oil companies have made several types of arrangements. In some cases the chemical company installs a plant near a large refinery which can supply raw materials. In another case, a chemical plant operated by a chemical company may be located within economic distances of several refineries from which they purchase raw materials. Oil companies may create jointly owned subsidiaries which have one or more chemical plants. A petroleum company may also create a wholly owned subsidiary for manufacturing and marketing chemicals (41).

Shell Chemical Company has under construction a plant for the manufacture of glycerine from propylene which is scheduled to begin operating in 1948. The plant will have an annual capacity of between 30 and 35 million pounds of glycerin and will cost 7 million dollars The process involves the chlorination of propylene and subsequent hydrolysis. In the course of the glycerine manufacture, a number of intermediates are to be made, including particularly allyl alcohol (41, 42).

The Shell Company is also making a soil fumigant known as D-D by the chlorination of propane-propylene fractions of cracked gases. This mixture is toxic to nematodes and wireworms which have severely blighted extensive agricultural areas. Crop yields have been increased 100 to 250 per cent after fumigation. Particularly good results have been shown in the Hawaiian pineapple fields (41).

The Oronite Chemical Company, a subsidiary of the Standard Oil of California, has a plant for making phthalic anhydride with a capacity of 8 million lbs a year to supplement the inadequate supplies of this chemical made by the oxidation of napthalene from coal tar. The Oronite Chemical Company is also manufacturing a group of detergents by sulphonating alkylated aromatics. In 1946, 125 million lbs of detergents were made from petroleum and in 1947 production was expected to be more than twice this amount (42).

In the field of solvents, a petroleum or natural gas provides slightly over 5 per cent of the country's methyl alcohol, 50 per cent of its ethyl alcohol, 100 per cent of normal butyl alcohol and 90 per cent of amyl alcohol. 100,000 tons of plastics annually are derived wholly or in part from ethylene. These include the polyethylenes, a substantial portion of the vinyl resins, ethyl cellulose and polystyrene (43).

In 1946, 3.8 billion lbs of chemicals were manufactured from petroleum exclusive of benzene, toluene, xylenes and other aromatic hydrocarbons (42).

About $350,000,000 is being invested for the manufacture of petroleum chemicals in the Texas Gulf area. Most of these plants are being built by chemical companies, although a substantial proportion are being built by oil companies (44).

The Fischer-Tropsch process is being adapted to the production of hydrocarbons and oxygenated compounds from natural gas. Two commercial plants are projected—one of which will use 64 million and the other 100 million ft of gas a day. In this process, the natural gas is oxidized at temperatures from 1480 to 1540 deg. C., at a pressure of 300 lbs. per sq. in., to produce mixtures of carbon monoxide and hydrogen which are then contacted with iron catalyst to produce gasoline, diesel oil and mixtures of alcohols, aldehydes, acids and ketones. A particular feature of these plants is the production of normal compounds instead of the iso compounds. The catalyst is used in finely powdered condition as a fluid, this being an adaptation of the Fluid catalytic cracking process. The larger (Stanolind Oil and Gas Company, Tulsa, Oklahoma) of the two plants is expected to produce about 6,000 barrels of 80 octane gasoline, 1,000 barrels of diesel fuel, and over 400,000 pounds of organic chemicals daily. The anticipated annual production (over 152 million lbs) of these chemicals from this plant is shown in the chapter on the Chemical Industry.

Illustrations used in this section were provided by Standard Oil Co (Ohio), Socony Vacuum Oil Co, Gulf Oil Corp, Lummus Co, Universal Oil Products Co, Standard Oil Co (N. J.).

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CHAPTER XXII

PLASTICS

by GORDON M. KLINE

During the war period, 1939-1945, the plastics industry quadrupled in size. Many wondered whether the industry could maintain this high level of production in peacetime The years 1946 and 1947 have supplied the answer. Reconversion has not meant retrenchment, on the contrary, each year has seen the establishment of new production records

An indication of continued expansion of the industry is the considerable number of surveys which have been conducted regarding the sources of its raw materials and its present and potential markets Some which have been published deal with coal and petroleum (1), acetylene and ethylene (2), formaldehyde (3), and acrylonitrile (4). The facts seem to point quite conclusively to petroleum, natural gas, and chemicals derived from annual crops, such as furfural (5, 6), for the future supply of chemicals for the plastics industry

MATERIALS

Phoresin

An interesting addition in 1947 to the roster of synthetic resins is a thermoset produce made by the polymerization of diallyl phenyl phosphonate (7). This derivative of phosphoric acid can be copolymerized with other monomers to impart flame resistance, increase in index of refraction and hardness, and a decrease in solubility The index of refraction of the pure polymer is 1.57 By copolymerization with methyl methacrylate, a product having the same index of refraction as that of glass can be synthesized, thus permitting the production of glass cloth laminated structures with a high degree of transparency.

Terylene

Another new and promising polymer is a British product (8), made by polycondensation of terephthalic acid and ethylene glycol. It yields fibers with a high modulus of elasticity and outstanding resistance to heat, light, and water. The fibers are thermoplastic, resistant to micro-organisms and chemicals, and have a high ratio of wet to dry strength.

Polytetrafluoroethylene

Availability of the polymer made from the tetrafluorine derivative of ethylene (9) was announced during 1946, although appreciable quantities of it had been made during the latter period of World War II for military applications. Polytetrafluoroethylene, marketed as Teflon, is inert to all types of chemicals except molten alkali metals It does not have a true melting point but does undergo a solid phase change at 620 deg. F. with a corresponding sharp drop in strength It gives off small amounts of fluorine-containing gases above 420 deg. F Because of its high softening it can be shaped only by special techniques (10). Suggested applications include coaxial cable spacers, valve packing, gaskets, and plug cocks and tubing for chemical plant equipment (11)

Polyethylene

The parent substance of the foregoing tetrafluorine derivative has only been made in commercial quantities in this country since 1943 (12, 13). Ethylene is available in natural gas and can be made cheaply from petroleum and coal. High molecular weight paraffin-like polymers are obtained only at high pressures, 1000 to 2000 atmospheres (14) Its primary use during the war period was for electrical insulation on radar wire and cable because of its excellent dielectric properties. Several reports on its characteristics have indicated that many other important uses may be expected from its combination of flexibility and toughness over a wide range of temperature without plasticizer, low water absorption and impermeability to moisture, chemical inertness, and low specific gravity (0 92-0 93). These possible applications include containers, gaskets, battery parts, packaging films, chemical equipment, and flexible tubing of various types (15).

Styrene Derivatives and Copolymers

Plastics engineers are well aware that the more than 400 million lb plant capacity for the manufacture of styrene, built to meet the requirements of the synthetic rubber program, represents a tremendous potential source of raw material for the production of polystyrene and styrene copolymer resins. The forerunners of numerous developments in this field were announced during the war (16-18). The primary objectives have been to improve on the heat resistance and impact strength of polystyrene and secondarily to retain to as great an extent as possible the excellent electrical characteristics of the latter material.

Styrene resins forged ahead in 1947 to a new production record in a diversity of applications. A polystyrene molding material with an A.S.T.M. heat distortion point of 87-88 deg. C. compared to 78-80 deg. C. for standard polystyrene became available (19). It is anticipated that the higher heat resistance of this compound will be advantageous in household merchandise, surgical and medical appliances, industrial equipment, light fixtures, and electrical insulating parts. A styrene-base casting resin resulting from war-time research on the proximity fuse was described by the National Bureau of Standards (20). The compound has excellent dielectric and chemical resistance properties and may be especially useful in high-impedance control devices in steel mills, plating plants, and other factories handling corrosive chemicals as well as in the potting of components for radar and other electronic equipment.

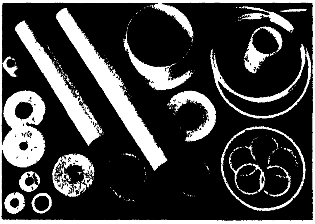
Polydichlorostyrene polymers are hard, transparent, colorless substances which resemble polystyrene in chemical resistance, solubility, and general appearance (21). They have heat distortion temperatures ranging from 240 to 265 deg. F., excellent electrical characteristics, good strength, machinability, and moldability. It is not necessary to add stabilizers to prevent dehydrohalogenation as is the case with polymers containing chlorine attached to an aliphatic structure. Polydichlorostyrene is nonflammable and can be injection molded or extruded. Copolymers of the dichlorostyrenes with butadiene and other unsaturated compounds yield rubberlike materials which are characterized by oil resistance, resistance to heat, and low water absorption.

Another styrene copolymer, Plexene M, was announced in 1946 It has an A.S T M. heat distortion point of about 190 deg F. and is resistant to gasoline, commercial inks, acids, alkalies, and dilute alcohol (22).

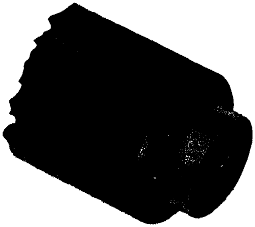
Vinyl Ester Resins

Considerable attention was focused on the vinyl resins during the year as several new plants came into production or neared completion Approximately 175 million lbs were produced in 1947. Further advances in the art of coating, dipping, molding, and casting resin-plasticizer pastes (23) were recorded. Synthetic rubber of the butadiene-acrylonitrile type has been compounded with vinyl chloride resins to combine the oil, chemical and age resistant properties of the latter with the solvent resistance and flexibility of the former (24). The combination avoids the troublesome factor of plasticizer migration. Resistance to aging, corrosion, solvents, flexing, and abrasion, coupled with the adaptability of the materials to practically all plastic processing techniques, accounts for employment of these vinyl resins in electrical equipment, extruded tubing, screening, gaskets, coated fabrics and papers, packaging films, and molded aircraft and motor vehicle parts (25)

A high-solids water dispersion of vinyl chloride resin has been found to be suitable for impregnating paper and fabric and for the manufacture of hospital sheeting and foul weather clothing The latex method eliminates costly solvents and solvent recovery systems and promotes better adhesion of the resin to fibrous bases (26). Dispersions of the vinyl resins in organic nonsolvents

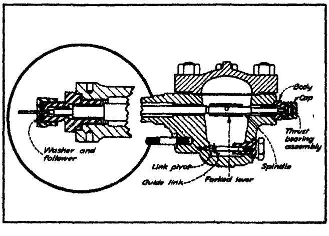


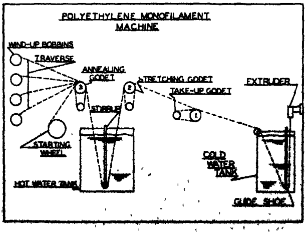
"Teflon", new tetrafluoroethylene resin, retains its strength and form at high temperatures.



Cross-sectional view of television transmission cable which has been insulated with polyethylene plastic.

Replacing rubber and leather gaskets, polyethylene serves as a pressure-tight bearing washer on fluid meters.





(organosols) have also proved useful. (27).

A vinyl resin made by copolymerizing 85 parts vinyl chloride, 15 parts vinyl acetate, and 1 part maleic acid was found to give coatings which adhere well to smooth surfaces after air-drying The good adhesion is attributed to the presence of unreacted carboxyl groups contributed by the maleic acid (28).

Polyvinylidene Chloride

Manufacture of these resins was initiated by the Dow Chemical Company in 1939 using the trade name Saran When molded under proper conditions, polyvinylidene chloride produces articles of high impact strength, abrasion resistance, dimensional stability, and chemical inertness. Fittings and parts molded of these resins are particularly valuable in the chemical industry. Pipes of this material, for example, are superior to iron pipes for disposal of waste acids A suction pump has been fabricated completely from polyvinylidene chloride with the exception of two metal parts The pump attaches to acid carboys, eliminating splashing Because of its resistance to oils, water, alcohol, and other chemicals, it has a wide range of usefulness in transferring bulk perfumes, flavoring extracts, syrups, and the like. Film made of this resin is suitable for various types of packaging, including food products, medicinals, and metal parts (29). A new series of vinyl-vinylidene chloride copolymers was announced in 1944 under the name Geon (30) During 1947 polyvinylidene chloride extended its markets as filaments (31) and latex (32, 33).

Polyvinyl Alcohol

Production of polyvinyl alcohol by E. I. du Pont de Nemours and Company, Inc., and its conversion into rubberlike products by the Resistoflex Corporation were under way in this country in 1940, based on earlier development work in Germany (34). The applications of polyvinyl alcohol include adhesives, emulsifying agents, textile sizes, oil-resistant tubing, chemical-proof gloves, and antistatic hammers for forming light metals. It is useful for washers, diaphragms, gaskets, and other parts requiring various degrees of rigidity and resistance to oils, solvents, and wear; however, they are susceptible to attack by water((35).

Polyvinyl Carbazole

This polymer was originally manufactured in Germany under the name *Luvican* (36). Because it had possibilities as a synthetic replacement for mica, a critical component of radio and electrical equipment, production was started in this country in 1943. The domestic product is called *Polectron,* its electrical properties and water resistance are comparable to those of polystyrene, its softening point is much higher, but its impact strength and other mechanical properties are inferior To obtain a tougher product it is oriented by extrusion and broken up into coarse fiberlike pieces These can be compression molded while still retaining their orientation and yield a comparatively strong molding By using a solution of the polymer in tetrahydrofuran, it is possible to cast thin foils which can be employed as a replacement for mica in condensed dielectrics (37).

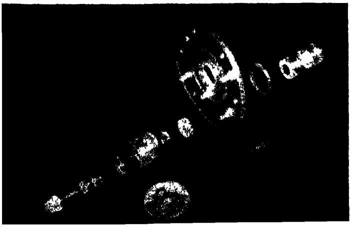
Furane Resins

Although the commercial production of 100 per cent furane resins dates from 1944, these materials have been under investigation by the Quaker Oats Company since the early 20's. They stem from furfural which is produced by the dehydration of the pentoses associated with cellulose in corncobs, oat hulls, corn stalks and related farm products Other furane derivatives used to make resins include furfuryl alcohol, tetrahydrofurfuryl alcohol and hydrofurfuramide. Furane resins made by the Furane Plastics and Chemical Company and U. S Stoneware Company have found applications in adhesives, corrosion-resistant coatings, and impregnation of plaster of paris dies (38). A new furane-asbestos composition made by the Haveg Corporation has proved to be more saitssfactory in chemical plant equipment than the previously used phenolic-asbestos material (39) Because of its resistance to many chemcals, this furane resin has extended the use of plastics into applications involving contact with alkalies, hydrocarbons, halongenated organic compounds, and organic acids (40)

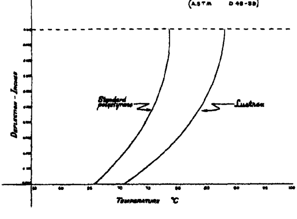
Silicon Resins

These high polymers are the result of research in the field of organosilicon compounds dating as far back as 1871 A British investigator, Kipping, initiated in 1904

Especially machined Textolite parts used in a tower head of an antenna pattern plotter.



New "boilable" polystyrene Lustrex shows better heat-distortion properties than standard polystyrene.



experimental work on the silicon monomers and their low molecular weight condensation products, which laid the foundation for their later commercial development in this country. Silicon is an element occurring in ordinary sand The organosilicon resin is comprised of a network of silicon and oxygen atoms with hydrocarbon radicals attached to the silicon element. This oxygen-silicon structure in high polymers was previously known only in inorganic products such as quartz, glass, asbestos, and mica. Silicon resins were first made available commercially in 1943 by the Dow Corning Corporation

The silicon resins found immediate applications in the electrical field because of their resistance to heat, up to 500 deg. F. In combination with glass fiber tapes and fabrics, they represent a revolutionary advance in electrical insulation (42). Silicone rubber, which has a curious combination of the properties of rubber and putty, has found use as a gasket material on searchlights and aircraft (43). Baked coatings based on silicon resins have been developed for protection of ranges, radiators, heat exhaust pipes, and stacks (44). Treatment of textiles, mirrors, windshields, wallpaper, etc, with organosilicon compounds renders their surfaces water repellent (45). Adaptation of these resins to standard laminating practice in the preparation of glass fabric panels was announced in 1946 (46, 47).

Resorcinol-Formaldehyde Resin

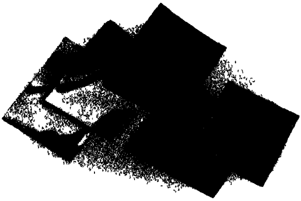
This new member of the phenolic class of resins appeared in 1943 The two hydroxyl groups attached to the benzene ring result in three extremely reactive positions Their reactivity is such that the resin cures rapidly at temperatures from 60 to 150 deg F. under nearly neutral conditions. It has been found to be especially advantageous for assembly bonding of wood and other materials which are deteriorated by the strong acids used in cold-setting urea and phenolic adhesives (48). This type of adhesive, first introduced in this country as Penacolite, has been particularly useful in the shipbuilding and aircraft construction industries, manufacture of plywood sheet and tubing, and bonding of plastics, rubbers, and metals (49).

Unsaturated Polyesters

Beginning in 1942 with the allyl resins manufactured by the Columbia Chemical Division, Pittsburgh Plate Glass Company, under the designation CR (Columbia Resins) (50), polyesters with unsaturated ethylenic groups built into them have been available. These unsaturated polyesters undergo a true polymerization in which combination of the monomers occurs through carbon to carbon bonding. In the process of polymerization cross-linked three-dimensional structures are formed without the splitting off of water or other chemicals and therefore these resins can be processed at low temperatures or by single contact. Hence these materials are sometimes called contact resins.

The unsaturation may be introduced into the polyester resin by the use of an unsaturated acid, such as maleic acid, or an unsaturated alcohol, such as allyl alcohol. The reaction mixture may also contain saturated polybasic acids and saturated polyhydric alcohols. CR 39 resin, for example, is essentially composed of carbonic acid, ethylene glycol and allyl alcohol. Later types of

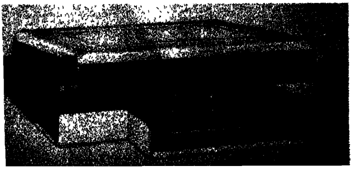
Types of U. S. Navy cable jacketed with polyvinyl chloride.



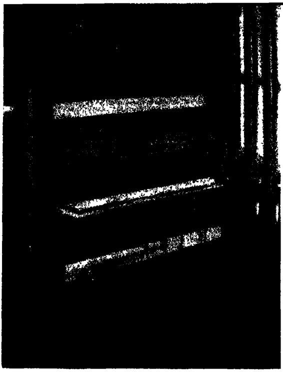
Three polished samples of sheeting at left are composed of Geon polyvinyl chloride plastic and Hycar acrylonitrile rubber. Two embossed samples at right are of phenolic resin and acrylonitrile rubber.

New Saran fabric handbag combines durability, cleanability, freshness of fabric and sheen.

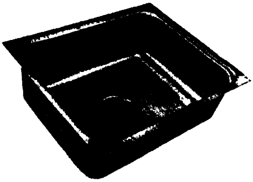
Plastic ice cream cabinet lid is reported to be 30 per cent lighter, more efficient and stronger than conventional models.



A plug-in multi-stage electronic control unit is "potted" in casting resin developed by National Bureau of Standards.



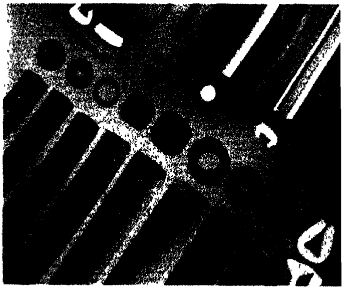
In pressing sheet mica, silicone rubber is reinforced with layers of asbestos cloth to insure an even bond.



This light weight sink is made of glass fiber warp mat bonded with BCM, a low-pressure laminating resin.

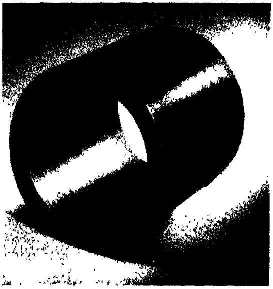
A hypodermic needle hub of nylon is hygienic, does not freeze to syringe nor discolor after repeated sterilization.

World's largest transparent plastic bubble is carefully checked for construction flaws after this final draw.

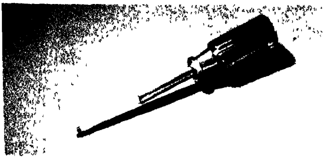


Extruded tubes, rods and fabricated stock made of silicone rubber.

A complete line of heavy duty plastic tableware has been produced with shock- and boiling-resistant Melmac.



Large bushing used on an electroplating machine where corrosive conditions prevent use of metals.



This nylon shafted screw driver is one of the first developments of nylon for insulating hand tools.

Low-voltage telephone wire, used by combat troops for distances up to 10 miles, combines desirable properties of polyethylene and nylon.

Forticel, a new cellulose propionate plastic, combines beauty with excellent mechanical and physical properties suited to varied applications.

Plastilock 500 showed satisfactory adhesion to aluminum. It is a water- and oil-resistant adhesive.

unsaturated polyesters generally have been mixed with other compounds containing ethylenic groups, such as styrene, which will copolymerize with the unsaturated groups in the polyesters during the polymerization process (51, 52)

These low-pressure resins have removed the size limitation which presses and steel molds previously placed upon molded plastics applications and have made possible the economical production of small numbers of pieces Rapid advances were made in this field under the stimulus of wartime requirements for aircraft parts, radar domes, and other military items which were readily fabricated using these resins with various reinforcing materials. Laminates of this type are under consideration for use in the manufacture of light weight transport, prefabricated housing panels, ducts for air-conditioning systems, luggage, and other products of large bulk (53, 54).

The unsaturated polyesters also are adaptable to casting and are available as transparent thermoset cast products The allyl diglycol carbonate resin provides a rigid transparent sheet which has outstanding resistance to abrasion, chemicals, crazing, and distortion under heat (55).

Nylon

The scope of the market for nylon resins (56, 57) was expanded during 1947 Among the applications explored for this versatile plastic were rope (58), watch straps, lock nuts, grommets, conveyor belts, and gyro parts (59) The properties of polyamides made with various diamines and dibasic acids were described (60). Culmination of 12 years of research work brought the announcement that furfural will be used as the raw material for the manufacture of hexamethylenediamine, one of the main ingredients of nylon resins (5). Furfural is obtained from agricultural sources, such as oat hulls and corncobs, hence it is available in essentially unlimited quantities as an annual crop.

Acrylics

An acrylic injection molding compound with an A.S.T.M. heat distortion point of 90 deg. C. was announced in 1947 (61). Another innovation in this field was a process for synthesizing methyl methacrylate from acetylene and acetone (62). A scratch-resistant coating for acrylic plastic consisting of hydrolyzed ethyl silicate and polyvinyl acetate was reported (63). Polyacrylonitrile fibers (4) characterized by flexibility, resiliency, high tenacity, and resistance to heat, light, and chemicals are undergoing development.

Thermosetting Resins

The chemistry and technology of phenol (64-66), urea (67), melamine (68), and furfural (69) resins received attention. A phenol-furfural resin varnish (6) developed for laminating is claimed to impart better electrical and mechanical properties than does the cresol-base varnish and to be free from the uncertainty of supply and nonuniformity of the latter product. A continuous board made from sawdust and cresol-formaldehyde resin with the aid of electronic heating promises to help meet the shortage of wallboard in Great Britain (70). Improvement in the properties of wood by treatments with thermosetting resins extended the markets for both materials (71-73)

Cellulose and Lignocellulose Plastics

Recent developments in the field of cellulose plastics include the marketing in 1945 of cellulose propionate molding compound (74, 75) and in 1947 of cellulose acetate propionate plastic (76). Further activities with ethyl cellulose (77), carboxymethyl cellulose (78), cellulose acetate butyrate (79), and cellulose phthalates and tetrachlorophthalates (80) were reported Production in Canada of a low-melting point, moldable lignin was announced (81). The material is currently used in a phenolic-lignin enriched, paper-base laminate employed for decorative purposes in buildings. Other uses for lignin were reviewed (82, 83)

Compounding Materials

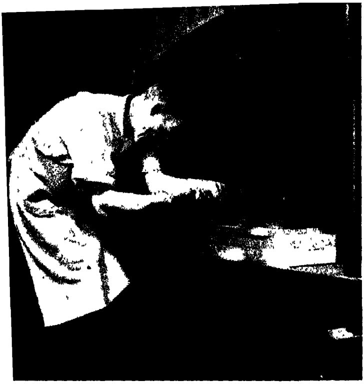
Surveys of particular groups of plasticizers were published (84, 85) Experimental and theoretical examination of plasticization phenomena received the attention of numerous authors (86, 87) A new source of fillers for plastics and adhesives became available when a bark processing plant (88) was put in operation in the State of Washington. Noteworthy articles reviewed developments in fillers (89, 90), fungicides (91), coloring materials (92-94), and peroxide catalysts (95).

APPLICATIONS

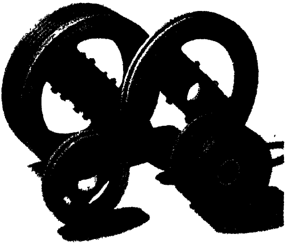
It would be difficult to single out any particular category of products as outstanding with respect to progress in the utilization of plastics during 1947 Rather, the year was marked by continuing advances in many diverse outlets, such as telephones (96), sound recordings (97), radio (98), photography (99), printing (100), refrigerators (101), luggage (102), flooring (103), signs (104), business machines (105), housings (106), furniture (107), boats (108), tools and jigs (109), ion exchangers (110), core binders (111), bearings (112), and electrical insulation (113) Other industries that employed plastics to improve their equipment and products include brewing (114), textile (115), paper making (116), power metallurgy (117), and chemical manufacturing (118).

Transportation

New uses were reported for plastics in the transportation industries Interior paneling with wood grain effect for station wagons, made of phenolic paper-base laminate (119), highlighted developments in the automotive field (120) Laminated seat backs, vinyl upholstery and shades, and acrylic signs and windows are among the increasing number of applications of plastics on buses (121) Practically all types and forms of plastics are represented in the accessories, decoration, lighting equipment, and glazing of the Train of Tomorrow (122), indicative of another expanding market for these materials. Published reports concerning developments in the aircraft field were fewer than in the previous years of intense expansion of this industry; the applications discussed included propellers (123), bullet-proof fuel tanks (124), and transparent enclosures (125).

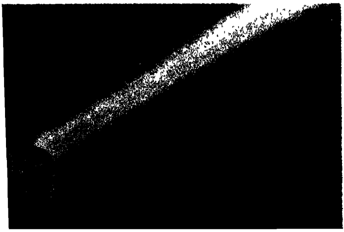


Laminating a rough block for aircraft patterns.



Wood sheaves for V-belt drives are made of straight-grain, kiln-dried hard maple with powdered casein glue. Laminated construction gives superior strength.

Honeycomb core being coated with synthetic resin adhesive, preparatory to facing with wood or metal sheets.



Medical

Resinous pills that are taken internally as a treatment for stomach ulcers, functioning by absorbing acid (126), and artificial eyes (127) made of methyl methacrylate resin were among the medical applications reported. The manufacture of acrylic and styrene lenses (128) for television, camera, projector, railway signal, and other optical equipment was described; other optical applications of plastics were reviewed (129, 130).

Building

Plastics are still spoken of hopefully in some quarters in connection with the housing problem, but cost and supply are far out of line with those of the common building materials (131). Two new developments in this field were described, one a resin-bonded sawdust timber, evolved in Great Britain, for conventional wood applications (132), the other a honeycomb-core aluminum-faced panel proposed for use in prefabricated housing (133). The plywood industry, which in 1927 used no synthetic resin adhesives, took more than half the approximate 80 million lbs produced in 1946 (134). Polystyrene tiles (135) represent a major new material for adding color and serviceability to kitchen and bathroom walls, their low water absorption, excellent dimensional stability, and resistance to discoloration and staining are important factors in this application.

Textiles

Further additions to the list of resin treatments for fibers to improve their performance properties were announced (136, 137). These finishes provide control of the shrinkage of wool, retention of crispness in sheer fabrics under moist conditions, durability of glazed chintzes when washed, moisture (138) and stain resistance to many textile products, and flameproofing (139). Developments in coated fabrics (140) and in synthetic fibers (141) were described.

Packaging

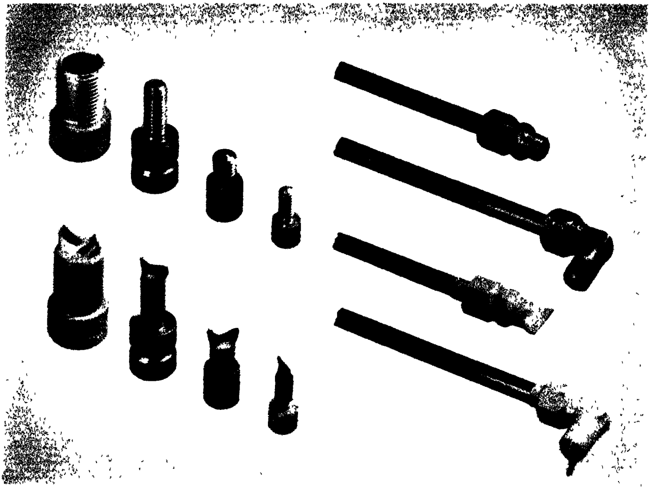
The packaging industry continues to consume large quantities of vinyl, vinylidene, styrene, polyethylene, cellulose acetate, and rubber derivatives in the manufacture of transparent containers, coated papers and textiles, and wrapping materials for display and protective purposes (142). The rapidly growing frozen foods branch of the industry has adapted plastic films (143) and hot-melt coatings (144) to their needs.

Coatings

The No. 1 customer of the synthetic resin trade, the organic protective coatings industry, explored still further the practically infinite combinations of film-forming bases and other materials used in formulating paints and lacquers (145, 146). Developments in the use of coatings based on cellulose derivatives (147, 148), vinyls (149), phenolics (150), and rubber (151) were described.

Adhesives

Plywood and laminated wood products are the major consumers of resinous adhesives (152-154); reports relating to this field spotlighted developments in phenolic (155), resorcinol (156), protein (157), and urea (158) glues and the effects of acidity (48), moisture (159), temperature (160, 161), and marine organisms (162) on



Plastic caps fit over machined surfaces, as covering during shipment, storage, plating and fabricating operations.

joint strength. Other important uses for adhesives included automobile body assembly (163), brake linings (164), and optical lenses (165). Special adhesives for bonding metal (166), rubber (167), and plastics (168) were described. A portable electronic machine (169) which eliminates the necessity for placing electrodes on both sides of the part to be cured promises to extend the utilization of the thermosetting resin glues in such applications as wall coverings, flooring, gates, furniture, and the like. The ultra high-frequency unit transmits the current from an electrode down through the glue line as far as 1 in. distance away and back up to the other electrode, thus effecting a complete circuit and curing the resin adhesive. Reviews were published concerning the general principles of selection and application of adhesives (170, 171) and the fundamentals of adhesion (172).

Industrial Plant Equipment

Plastics have been used by chemical engineers for many years in processes involving contact with highly corrosive acids and alkalies. The primary limitations have been size, heat stability, and cost. In many instances plastic coatings over metals have been used in lieu of molded or fabricated parts to offset these limitations. A few examples of developments in the chemical engineering uses of plastics will be cited to show the growing importance of this subject to both industries.

Metal plating plants have employed plastics extensively because of their resistance to acids. Among the applications recently described are acrylic plating barrels (173), polystyrene floats for stopping spray (174), shields for making sections of parts to be plated (175), and plating rack coatings (176). Several reviews of the uses of plastics in the plating industry have been published (177, 178).

The textile industry continues to find advantageous the toughness and chemical resistance of plastics. Thousands of spinning buckets molded of macerated-fabric-filled phenolic compound reinforced with woven fabric are used in the manufacture of rayon. Spinneret adapters injection molded of polyvinylidene chloride have been in service for over three years; these are in contact with an alkaline liquid on the inside and with an acid bath on the outside. Bushings fabricated from nylon resin or from nylon cloth impregnated with phenolic resin have given satisfactory performance in rayon spinning equipment. Splash guards and sight glasses of transparent methyl methacrylate resin are found on many machines in the textile field (179).

Resin-asbestos compositions (Haveg) have proved to be suitable for many types of chemical equipment. Phenolic resin has been commonly employed for this purpose, but under the pressure of wartime need a furane resin composition with superior resistance to strong alkalies and organic solvents was evolved. These resin-asbestos materials have been used for the con-

Production of thermoplastic laminates. Unlike conventional high-pressure laminates, these new materials contain thermoplastic resins such as cellulose acetate and ethylcellulose.

struction of storage tanks, reaction tanks, scrubbing and fractionating towers, suction filters, fume ducts, pickling tanks, and many special parts (180, 39). Numerous reports describing applications of plastics in chemical equipment have been published (181-184).

Vinyl resins, polyisobutylene, polyethylene, and phenolic resins are among the plastics which have been used for lining tanks (185-187). Baked phenolic resin coatings have been applied to the interiors of tank cars used to ship formaldehyde, latex, nylon intermediates, sulphuric acid, etc. Polyvinylidene chloride (Saran) has found ready acceptance in the form of piping for handling water, hypochlorite bleach, lubricating oil, and other liquids (188-190).

Fan blades for water cooling towers, made of wood veneers impregnated with phenolic resin, laminated and compressed, have proved to be superior to cast metal blades. Pump impellers molded of phenolic materials have given good service in contact with acids and gasoline. Other phenolic parts which serve where protection against acid is required are casters, gears, bolts, tank baffles, rollers, and valves (191). Recently a centrifugal pump for handling corrosive materials has been produced with all the liquid-handling parts made of Karbate, consisting of graphite impregnated with a furane resin.

Illustrations for this chapter were obtained through the courtesy of E. I. du Pont de Nemours, Bakelite Corp., General Electric Co., Monsanto Chemical Co., B. F. Goodrich Chemical Co., Dow Chemical Co., Frigidaire Division—General Motors Corp., National Bureau of Standards, Rohm and Haas Co., American Cyanamid Co., Polymer Corp., Celanese Plastics Corp., Bell Aircraft Corp., Casein Company of America, Glenn L. Martin Co. and Hercules Powder Co.

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CHAPTER XXIII

POWER INDUSTRY

by R. E. HANSEN

That the power industry successfully carried greatly increased war loads with relatively little increased capacity is now a matter of history. By forming large interconnected systems, pooling reserves, reducing overhaul of equipment, and operating plants long since relegated to cold standby, it was possible to meet unprecedented demands without delay and without impairing quality of services.

With the coming of peace it had been expected that loads would fall appreciably, giving utilities a breathing spell in which to catch up on maintenance and new construction Instead, total consumption of electric energy has already surpassed wartime levels, while reversion to standard time and lifting of *brownouts* and other restrictions have intensified peak loads Moreover, demands are increasing at almost as rapid a rate as in the early stages of war preparation.

As a result, few power systems have as comfortable a margin of reserve as they would like even for carrying present loads, and turbine manufacturers have on hand orders for some 13,000,000 kw to be delivered over the next 5 years While it is not expected that there will be any widespread power shortage, there may be short period emergencies when lack of adequate standby will impose local strains on power-supply systems. This expansion of power capacity is not confined to the United States; Canada, Great Britain, France, Russia and China expect to increase their power production within the next few years.

The most startling development of recent years is the announcement that nuclear reactions releasing large amounts of energy have been made to follow a controlled pattern capable of utilization on a commercial scale Conversion of such energy to a useful form and on an economical basis remains for the future, but in general the methods that will be employed are known; pilot plants now under construction will undergo trial operation in a short time (1, 2).

The mineral fuels will nevertheless continue for many years to supply a large proportion of our power requirements. Processes are being evolved that will increase supplies of liquid and gaseous fuels, for power generation as well as other uses. Improved methods of burning coal, in small installations as well as large, are also contributing to reduce the smoke pall that has hung over all industrial centers since invention of the steam engine.

Steam turbines are continuing the long, upward trends in size, efficiency, operating speed, steam pressure and steam temperatures. The economies of quantity production are being applied even in relatively large units through adoption by manufacturers and utilities of a series of standardized specifications In small sizes, complete plant designs are being standardized in so-called "packaged" plants.

Several large hydroelectric projects are under consideration Plans for development of the Yangtze gorge in China have been announced, indicating a project of greater magnitude than any now in existence.

A number of gas turbines are being built for power generation in Europe and South America, and experimental units are being tried out in the United States. Internal-combustion engines continue to be the most practicable means for supplying small blocks of power. The mercury-steam cycle is receiving renewed attention A new wind-power installation is being planned for Vermont, and a cannery in Tashkent employs solar power

ATOMIC POWER

Although an electric power plant utilizing atomic energy has not yet been put into operation, the possibility of such a plant was removed from the realm of speculation on August 6, 1945, when an atomic bomb exploded over Hiroshima, Japan It is now known that heat energy can be released in an atomic pile, the remaining problem being that of modifying the process so that the heat obtained will be in such form that it can be converted into electric energy, using the well known thermal power cycle. No insuperable difficulties are expected. A pilot plant is now under construction at Oak Ridge, Tennessee (a) that should be in operation by the spring of 1948, (b) others are under design.

State of Atomic Science in 1940

Prior to 1940, developments in atomic science were given little attention by the practical engineer, and from then until 1945 the subject was a tightly guarded secret Hence it is desirable at this point to give a brief history of the complete developments (3, 4). By the summer of 1940, the principal facts publicly known were·

1 In 1905 Einstein had given a mathematical demonstration indicating a possibility that mass and energy are interconvertible (5).
2. In 1938 Hahn and Stresemann had discovered the isotope uranium-235 and some of its properties.

An atom of uranium-235 undergoes fission when its nucleus is hit by a neutron, splitting into two atomic nuclei of roughly equal size. As all atomic nuclei are composed of protons and neutrons, and the heavier elements generally have a greater relative excess of neutrons, several of the latter are liberated each time a nucleus is split These are available to produce more fissions in a chain reaction, which may proceed slowly if relatively few neutrons encounter susceptible nuclei, or explosively if the density of the latter is sufficiently increased Neutrons necessary to start the chain are always present in small numbers by reason of cosmic ray activity, more can be supplied by any radioactive substance

The combined mass of smaller nuclei and excess neutrons produced on splitting an atom accounts for about 99 9 per cent of the original mass The remaining 0 1 per cent, representing the difference in *binding energy*, is released as X-rays and heat Binding energy is equivalent to the deficiency in mass of an atomic nucleus, below the combined mass of its equivalent in free protons and neutrons The production of any element by direct combination of free protons and neutrons would involve the release of energy, the amount per particle being greatest for those elements having atomic mass roughly half that of uranium Consequently, when uranium splits there is a residual to be released, amounting to about 38 9 billion Btu per lb —as much as would be obtained by burning 3,000,000 lb of coal.

If fissionable material exists as a small body, many of the neutrons released pass to the outside too quickly to encounter atomic nuclei, and energy is released slowly If the material is impure, many neutrons are absorbed by the impurities However, when a pure material such as uranium-235 exists as a large body, neutron density builds up rapidly, and energy is released explosively. The energy at the instant of release takes the form of radiation and kinetic energy of nuclear fragments, but it is quickly transformed into heat, the temperature at the center of a bomb blast being calculated at 20,000 deg F.

The requirement of size for explosion prevents the attainment of many fanciful schemes suggested, for taking advantage of the large amount of energy contained in uranium One such scheme was the construction of a new Panama Canal by planting pea-size uranium capsules at regular intervals, and detonating them simultaneously. There are no means now known (at least not publicly) for detonating small charges of fissionable material.

Naturally occurring uranium contains about 99.3 per cent of the inert isotope of mass 238, and only 0.7 per cent of uranium-235, with negligible traces of uranium-234. The problem confronting atomic physicists in 1940 was the separation of uranium-235 in sufficiently pure form.

Wartime Developments

In view of the turn taken in the European war in the spring of 1940, the United States government, with the cooperation of the governments of Canada and the United Kingdom, undertook to complete the research and development necessary to utilize atomic energy for military purposes.

The first problem was to obtain large quantities of purified natural uranium. In 1941, only a few grams of pure uranium existed. Before large quantities could be produced, commercial methods of purifying ore and reducing it to metallic form had to be worked out Cost of the metal in January 1943 was $22 per pound, improvements worked out since then may have reduced the price considerably

Isotope Separation

A plant for separation of uranium-235 was built at Oak Ridge, Tennessee Four methods of separation were used or tried (a) thermal diffusion of a fluid salt of uranium, in which the lighter isotope tends to concentrate at top of a vertical tube, (b) diffusion of a gaseous salt through a semi-permeable membrane, the lighter isotope tending to diffuse more readily (6), (c) centrifuging of gaseous salt, and (d) electro-magnetic, taking advantage of differential magnetic deflection of a stream of charged atoms due to difference in mass In all methods a large number of repetitions are necessary before substantial purity is achieved Some processes are particularly effective through certain ranges of concentration, making it desirable to combine different processes For example, electromagnetic separation may be applied after the proportion of U-235 in the material has been substantially increased by thermal diffusion (7)

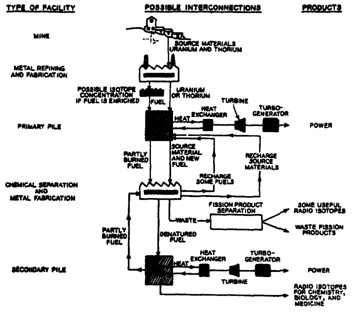
Plutonium Production

The production of plutonium is of greater interest to the power engineer than the separation of uranium isotopes, since its production involves the process that is expected to be used in producing power (8) In the wartime process, the chain-reaction pile produced plutonium, and gave off heat at low temperature as a by-product In the power-generation process, the same pile will operate at higher temperature, so that heat produced may be partially converted to electric power —plutonium will be the by-product For practical purposes plutonium is equivalent to uranium-235, in that it may be used in a bomb, or it may be used in a smaller pile for power generation.

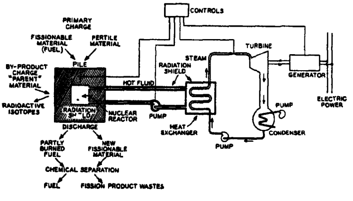
The chain-reacting pile consists of a number of cylinders of metallic uranium, embedded in graphite blocks Neutrons are produced when atoms of uranium-235 normally present undergo fission. Some of the neutrons produced are absorbed by atoms of uranium-234, increasing its atomic weight to 239. Uranium-239 spontaneously emits two *beta* particles, changing successively to neptunium-239 (atomic number 93) and then to plutonium-239 (atomic number 94).

Function of the graphite is to reduce velocity of the neutrons, as those most readily absorbed by uranium are the *thermal neutrons*—those with velocities such as might result from elastic collisions with molecules at normal temperature. Another important component of the pile is the moderator, made of neutron-absorbing material, this controls the rate of reaction, preventing a rapid rise in temperature such as occurs when a bomb explodes. Finally, the complete apparatus must be thickly shielded with lead or concrete, to protect workers from radiation.

The first chain-reacting pile to operate successfully on a self-maintaining basis was completed at Chicago in December, 1942. A larger plant was completed almost a year later at Clinton Laboratories, Oak Ridge, Ten-

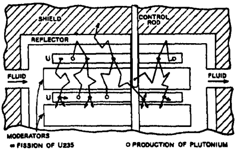

TYPE OF FACILITY
POSSIBLE INTERCONNECTIONS
PRODUCTS
MINE
SOURCE MATERIALS URANIUM AND THORIUM
METAL REFINING AND FABRICATION
POSSIBLE ISOTOPE CONCENTRATION IF FUEL IS ENRICHED
URANIUM OR THORIUM
FUEL
TURBINE
HEAT EXCHANGER
TURBO-GENERATOR
HEAT
PRIMARY PILE
POWER
PARTLY BURNED FUEL
SOURCE MATERIAL AND NEW FUEL
RECHARGE SOURCE MATERIALS
RECHARGE SOME FUELS
CHEMICAL SEPARATION AND METAL FABRICATION
FISSION PRODUCT SEPARATION
SOME USEFUL RADIO ISOTOPES
WASTE
WASTE FISSION PRODUCTS
PARTLY BURNED FUEL
DENATURED FUEL
HEAT EXCHANGER
TURBO-GENERATOR
HEAT
SECONDARY PILE
POWER
TURBINE
RADIO ISOTOPES FOR CHEMISTRY, BIOLOGY, AND MEDICINE

Atomic power facilities



Schematic diagram of atomic power plant

Basic elements of an atomic power plant are shown in model. Dr. K. H. Kingdon of General Electric was among first physicists to isolate Uranium 235.



Schematic structure of uranium pile

The potential utilization of atomic energy by industry has aroused much speculation. A technical possibility employing the fissionable atom, U-235, is envisaged in the diagram above. The schematic structure of the uranium pile is at the right. Into the nuclear reactor of the pile goes atomic fuel such as U-235 together with fertile materials to be transmuted into fissionable materials by the capture of neutrons. Energy is released by the fission of the nucleus of U-235. As the fragments fly apart, the kinetic energy released increases the vibration amplitude and velocity of the surrounding atoms in terms of sensible heat.

nessee The latter included a helium cooling system to remove heat at a rate of about 2000 kw, and produced sufficient plutonium to permit trying out processes for separating plutonium from fission products and unreacted uranium.

Major production of plutonium has been accomplished at Hanford Engineer Works near Pasco, Washington, where three piles were constructed (9). The first was completed in September, 1944, and the third in early 1945. Water from the Columbia River is used to remove heat from these piles, at rates possibly as high as 500,000 kw per pile.

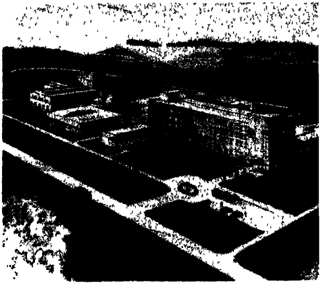
Present Situation

The first power-generation pile is under construction at Oak Ridge, and is expected to operate some time this year. Using a design suggested by Farrington Daniels, the pile will heat a gas—possibly helium, as in the first Clinton Laboratories pile—which will be used in turn to generate steam in a boiler Because the gas may carry radioactive material, the boiler-like pile will be shielded. Turbine and condenser, however, will probably be outside the shielded area (10)

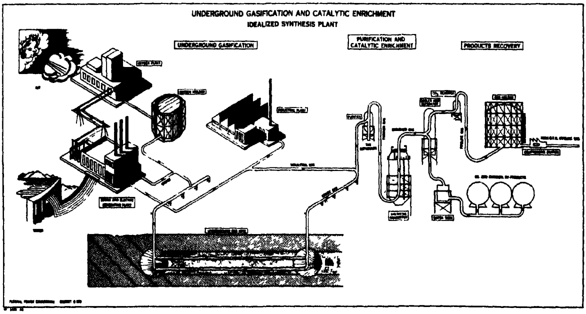
Power generation piles of other designs are being built at Hanford and Chicago (11, 12) Principle variable would be the heat transfer medium Water and molten bismuth have been suggested A future possibility is the use of helium or some other gas at high pressure with direct generation of power by the gas in a closed-cycle gas turbine

Current research at Knolls Laboratory at Schenectady, New York, includes the study of means for ship propulsion Because of the weight of shielding necessary, it is unlikely that atomic power will find application in any form of land or air transportation, and only in larger ships However, it may revolutionize naval warfare by making possible the construction of large submarines capable of high speed while submerged (13).

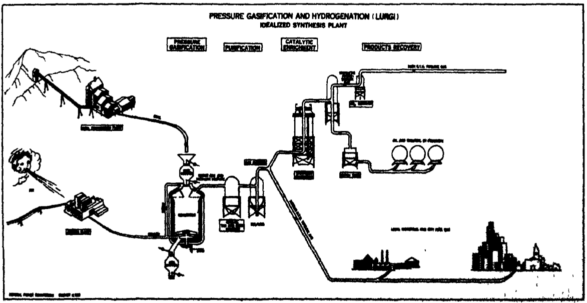
130 ton, 100,000,000-electron-volt betatron will produce a beam of high-velocity, high-energy electrons or beta rays. Another research tool in the quest of power from the atom.



"The Knolls' Atomic-Power Laboratory, as previewed by architect's proposal, will commence operations in 1948 under supervision of G-E for the U. S. Government.


UNDERGROUND GASIFICATION AND CATALYTIC ENRICHMENT
IDEALIZED SYNTHESIS PLANT
UNDERGROUND GASIFICATION
PURIFICATION AND CATALYTIC ENRICHMENT
PRODUCTS RECOVERY

Experimentation, as illustrated by the drawings above and below, attempts to efficiently utilize cheap raw materials for gas synthesis. New processes for manufacture of oxygen to make synthetic fuel industry an economic reality.


PRESSURE GASIFICATION AND HYDROGENATION (LURGI)
IDEALIZED SYNTHESIS PLANT
PRESSURE GASIFICATION
PURIFICATION
CATALYTIC ENRICHMENT
PRODUCTS RECOVERY

The major outlines of the scope of atomic power development appear to be fairly well defined (14 to 22). The nature of the process demands that power generation be carried on in large-scale units. It is expected that there will be two main types of plants Primary piles will produce power in the range from 100,000 to 500,000 kw, from natural uranium, with plutonium as the by-product These plants will be operated under direct supervision of government agencies, or perhaps international bodies, so that no plutonium will be diverted for destructive purposes.

Secondary plants will be smaller, approximately 20,000 to 100,000 kw. Plutonium *fuel* will be obtained from primary-pile operators These plants may be operated by utility and industrial companies, with supervision only sufficient to assure that all plutonium supplied will be used as intended

Present indications are that nuclear energy will have difficulty in competing with fuels, except where the latter are penalized by unusually high transportation costs—as in the Far North, or in rough, mountainous regions not accessible by rail Published estimates indicate that the initial cost of an atomic power plant will be more than twice that of a comparable coal-fired steam plant Even on the assumption of government financing, with freedom from taxes and low interest charges, such a plant could compete with coal only if the latter costs $10 per ton With private financing through business-managed tax-paying utility companies, coal could cost much more than $10 per ton and still prove more economical (23 to 27)

STEAM POWER

Fuels

The mineral fuels remain as in the past our major source of mechanical and electrical power. Long-term trend of development is toward a more efficient and complete use of available fuels, not so much because of a limited total supply, but because expansion and diversification of demand indicate the need for planning, to prevent shortages of specific types of fuel (28). Some minerals formerly considered important only as fuel are finding use as chemical building blocks. For example, synthetic rubber alone requires significant amounts of the butylene fraction of petroleum, coal-tar benzene, and carbon-black made from natural gas.

Natural gas reserves, quoted as recently as 1943 at 60 trillion cubic feet, are now considered to be nearer 200 trillion (29, 30). Large discoveries, mostly in Texas and nearby states, have set off a spurt of pipe-line building unparalleled since the early 1930's. The Big Inch and Little Inch lines, used during the war to transport crude oil and refined products, respectively, to the Atlantic Seaboard, have been sold to a private company for use in carrying natural gas to that area. Other lines are under construction or discussion from Texas to California, Tennessee, West Virginia, Michigan, Wisconsin, South Carolina, Florida, and intermediate places. While the gas so transported will be used primarily for domestic and small commercial services, it is probable that off-peak use of gas in power plants will in some cases be necessary in order to improve the load factor and increase earnings.

One experiment has been completed in the United States, and more will probably follow, to determine the practicability of gasifying coal underground, eliminating the need for mining—except to bore holes through which steam and air perhaps with oxygen added, can be circulated and gas withdrawn (31) Gas produced is of low thermal value, and would be useful in mine-mouth power plants or industries, or for conversion to higher-grade fuel by synthesis Results achieved so far are encouraging but further experimentation is required before the process can be considered commercially practicable. Similar experiments have been carried on in Russia for several years, but adequate data on results have not been published (32)

A process of making high Btu gas, mainly methane, from coal, known as the Lurgi process, has been used in Germany and may soon be employed in the United States If practicable, this process might accomplish for the coal-burning regions what the discovery of natural gas did for the southwestern part of the United States—the elimination of smoke and soot. Such a prospect is as encouraging as anything that atomic energy offers

New petroleum reserves in nature are not being discovered rapidly, but are keeping pace with production Synthetic processes being developed, however, will add materially to total reserves (33 to 38) Two plants are under construction for making oil from natural gas, and another is being planned for using coal All will employ the Fischer-Tropsch basic method, starting with equimolecular mixture of carbon monoxide and hydrogen Any hydrocarbon compound, or form of elemental carbon, can be converted to such a mixture by incomplete combustion or by its reaction with steam, and therefore can be considered a raw material for synthetic oil If synthetic oil refineries are built in coal-mining areas, there may be heavy residual oils to be disposed of to power plants in those regions.

Summing up the possible effects of these developments on availability of fuel for steam power, there is (a) probably more widespread use of off-peak pipeline gas; (b) possibility of using gas produced from coal underground, in plants located at the mine-mouth, (c) competition from liquid-fuel industry both for natural gas and for coal, (d) more heavy fuel oils available for power production, including certain fractions of synthetic oils, and (e) changes in types of oil available for internal-combustion engines.

Boiler Plant

Coal Handling: Receiving and handling of coal is being expedited in several ways During winter months, slack coal is often received frozen solid in the car. Use of thawing sheds, or even open burners in pits under the tracks, is increasing Loosening of compacted coal in unloading is effected with the *shakeout*, a vibrator placed across the top of the car.

Old-time drag-scrapers for spreading and reclaiming coal in storage yards are being replaced by bull-dozers and carryalls (40). These are more flexible in operation and simpler to maintain. The bull-dozer is run over the pile several times after spreading to give compactness, reducing risk of spontaneous combustion.

Coal Firing: Use of the spreader stoker is increasing in smaller plants Simpler and less expensive than pulverized-fuel firing, the stoker fires small sizes of crushed coal partly in suspension and partly on the grate In most designs the coal is projected horizontally or with a swirling motion The smaller particles ignite in mid-air and are carried away with combustion gases while burning The larger pieces fall on the grate where they burn as in conventional stokers (41)

Recently the development of a horizontal cyclone burner for crushed coal was announced. With this burner, low-grade coals having low-fusing-point ash can be burned, with removal of most of the ash in the form of molten slag Midwestern power plants have long been plagued with rapid slag formation on boiler tubes reducing steam capacity and requiring frequent cleaning The new burner is likely to prove attractive for smaller installations using crushed coal (42)

Following the trend of utilizing small-size fuels formerly considered as waste, several large installations have been completed or are under construction for burning anthracite culm in pulverized form Though one of the first pulverized-coal installations built nearly 20 years ago near Lykens, Pennsylvania, used anthracite coal, the greatest development of pulverized fuel firing has been with softer grades of bituminous Anthracite requires higher temperatures of preheated air, and offers some difficulty in burning (13)

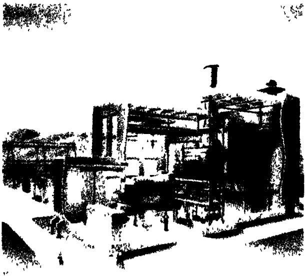
Sootblowing It is conventional in steam boiler practice to employ saturated steam from the drum for sootblowing This is now the main source of loss of water from the cycle, and in the case of high-pressure high temperature plants it constitutes a serious drawback since it requires the entry into the cycle of quantities of makeup water carrying solids in solution. These, in turn, may produce scaling on turbine blades

About 1930, a plant in South Amboy, New Jersey, and another at Bremo Bluff, Virginia, adopted compressed-air sootblowing Recently a report was made on results of installations of this kind at Oswego, New York, and at Huntley Station in Buffalo (44) While the system is expensive to install, it is considered to save substantial expenditures for feedwater treating equipment and for boiler capacity to provide steam Several new plants will employ the pneumatic system, and at least one company is planning to convert older boilers now using steam.

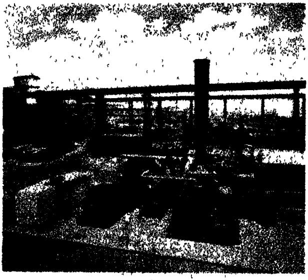
Pump Erosion Research is under way to determine what materials can be employed to resist erosion caused by high-pressure feedwater (45). Flow of water across a disk at controlled pressure differential for a specified period produces observable amounts of wear It has been found that chromium-bearing steels showed greatest resistance to erosion, an alloy with 5 per cent chromium and 0.5 per cent molybdenum being apparently best from an economical viewpoint. Bronzes and monel showed good resistance, and cast iron proved better than cast carbon steel Bakelite lacquer is suggested as a means of protecting old casings.

Acid Cleaning: Modern high-pressure boilers are difficult to clean by turbine-type cleaners, and a method of cleaning with dilute inhibited hydrochloric or sulfuric acid has been developed. Concentrations used

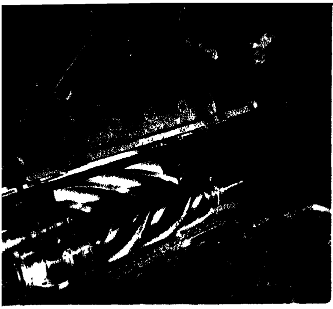
Gas turbine set for experimental operation using pulverized coal at the Brown Boveri shops in Switzerland.



A phantom view of standardized 5000 kw. packaged power plant location of units for steam electric station.



A packaged power plant of another manufacture is shown here for a test run prior to dismantling for export.



Lysholm positive-displacement compressor employed in the Elliott gas turbine.

81 250-kva steam turbine generator installed in the Springdale Station, West Penn Power Company.

range from 5 to 7 per cent Temperature and time are regulated to dissolve scale without removing metal in significant amounts Venting of hydrogen, produced in such manner as to prevent fire or explosion, is an important matter (46, 47)

Graphitization Several years ago it was discovered that carbon in carbon-molybdenum piping in some instances separated from the alloy as graphite, thus considerably weakening the material Research sponsored by utility companies led to the following conclusions (a) excessive use of aluminum for removing traces of oxygen promotes tendency toward graphitization, (b) carbon molybdenum steel is more resistant to graphitization than plain carbon steel, and (c) small quantities of certain metals, such as vanadium, tungsten and columbium, appear to stabilize steel against graphitization (48, 49, 50, 51). Carbon-molybdenum steel is used by General Electric Company (50) for temperatures up to 825 deg. F., as alloys sufficiently free from aluminum are not easily procurable For 900 to 950 deg F., chrome-molybdenum is sometimes used, for 1000 deg. F., 12% chromium, 5% cobalt and 3% tungsten; for 1050 deg. F., stabilized 18-8 stainless steel is required (52 to 56).

Turbines

Standardization: For almost 40 years large steam turbine-generators have been made to the customers' specifications. This practice led to a wide variety of designs, each intended to fit the particular needs of the plant in which it was installed. Sometimes these custom-built machines permitted substantial economies in overall plant cost or in operating expense. More often, however, minor variations introduced led to delays in engineering and manufacture, and added large but unidentifiable amounts to the cost of turbine-generators.

A series of eight steam turbine-generators are covered in a specification drawn up by a joint committee of American Institute of Electrical Engineers and American Society of Mechanical Engineers (57-58). The series covers sizes from 11,500 kw. to 60,000 kw. The three smallest units are specified to take steam at 600 lbs. per sq. in. gage, 825 F.; one size, 30,000 kw, uses steam at 850 lbs. per sq. in. gage, 900 deg. F., while for 40,000 kw, as also for 60,000 kw, two units are specified, one for 850 lbs per sq in gage, 900 deg F and the other for 1250 lbs per sq in gage, 950 deg F

Manufacturers have drawn up designs and published performance data for machines adhering to AIEE-ASME PREFERRED STANDARDS specifications, and given encouragement to customers, through favorable prices and delivery promises, to specify these machines when ordering Since the publication of specifications, the proportion of standard turbines ordered has been gradually increasing, and it appears probable that within a few years only a small number of specially designed turbines will be purchased There has been some discussion favoring the addition of at least one more unit in the 80,000 to 100,000-kw size range

Blading All major turbine manufacturers have announced development of a 23-inch blade for use in 3600-rpm turbines, on a 42 5-inch root diameter This gives a greater exhaust annulus area than has previously been available in units operating at this speed, which in turn permits greater capacity from simple single-casing machines Design of the blade must be considered quite an achievement, inasmuch as it must rotate with a tip speed of nearly 1400 ft per second (59).

Another recent development is the variable-angle warped-surface blade, now used in lower-stage nozzles and buckets of 3600-rpm turbines of 50,000 kw and up. This design takes into account the variation in linear speed of the blade along its length due to rotation, which requires a variable angle of incidence for maximum efficiency In smaller units and with lower rotational speeds this variation does not reduce efficiency to a sufficient extent to justify the manufacturing complication.

Advanced Designs: Pressures, temperatures and speeds continue to rise The 850 lbs. per sq in. gage plant is fairly well standardized, there being few built for lower pressures, while 1250 lbs per sq in. gage is becoming quite common. Several plants for 1500 to 2000 lbs. per sq. in. gage are planned. Similarly, temperatures of 900 to 950 deg. F. are commonplace, and the first plant built for commercial operation at 1000 deg. F. is now in service (60). Several units to operate at 1050 deg. F. are under design. Nearly all units are built for 3600 rpm, even in the very large sizes.

The continued upward trends in size, speed and steam conditions may be illustrated by the following brief statements regarding certain units now under design or construction (61 to 68).

Essex—A 100,000-kw turbine-generator to take steam at 1250 lbs per sq. in gage, 100 deg F is on order for this plant at Newark, New Jersey It will employ the 23-inch bucket described above, and will operate at 3600 rpm.

Sewaren—A new plant in Woodbridge Township, New Jersey, will have three tandem-compound 100,000-kw units, taking steam at 1500 lbs. per sq in gage, 1050 deg. F. Five low-pressure stages will be triple-flow, the last stage having 3 rows of 23-inch buckets

Philip Sporn—A new plant at Pomeroy, Ohio, will have two cross-compound 125,000-kw. units. The high-pressure element will turn at 3600 rpm, taking steam at 2000 lbs. per sq in gage, 1050 deg F The low-pressure element will turn at 1800 rpm and take steam reheated to 1000 deg. F.

Twin Branch—One unit similar to those for Philip Sporn Plant will be added to this plant at Mishawaka Indiana. Already installed, there is a unit operating at 2300 lbs per sq in. gage, the highest pressure in commercial use for steam power generation in this country

In total, about 9,000,000 kw of steam turbine capacity is now on order with equipment manufacturers (69), a remarkably large amount. Other countries are similarly engaged in increasing amount of available capacity, notably Great Britain (70), and Russia (71).

Operation of High-Pressure Units Turbines built from 1937 to 1941 for operation at 850 lbs. per sq. in gage. 900 deg F., or higher, were so vastly superior to previously existing units that they were intended for continuous base-load operation It was contemplated by manufacturers and users alike that they would for a long time constitute relatively small nuclei of efficient capacity in systems made up largely of older turbines Some systems during the war. however, experienced phenomenal percentage load growth, and have installed or will install many large high-pressure units. These utilities now find that with all high-pressure equipment operated continuously night loads required run at very low, uneconomical ratings

It is now thought that in certain cases savings in fuel cost result from shutting down high-pressure turbines and banking boilers, even when the off period is only overnight Such operating is. of course, harder on the equipment than a continuous full load, but manufacturers are confident the machines can be so operated without undue risk. Quick-starting methods that have been worked out add to savings achieved by such overnight shut-down (72).

Condensing Systems

The theory of condenser design has been well worked out and standardized Differences between condensers of different manufacture are due either to different ideas on how to secure effective steam distribution among the tubes, or to the need for fitting the equipment into a particular space

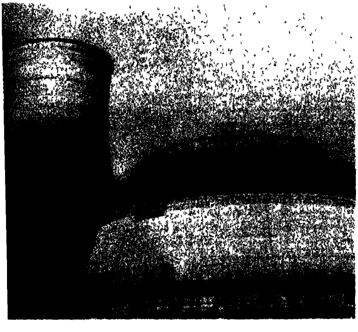
It has become almost a tradition that the condenser shall be beneath the turbine, and between the legs of the turbine pedestal This arrangement dictates the height of the condenser basement. Some designers, attempting to develop more economical building types, have employed one or two condensers at the sides of the turbines, permitting a low turbine foundation. This is a particularly advantageous arrangement in outdoor plants.

Cooling Towers

Until quite recently, nearly all sizeable steam power plants were built where large amounts of cool water could be obtained from rivers, lakes or tidal sources In the southwestern area of the United States, where rivers are flashy, some large lakes have been constructed at great expense solely to supply condensers of steam turbines. Even where adequate water supply is available, however, considerable expense is involved in utilizing it, as river banks may be low and marshy, subject to flood, or at considerable distance from load centers or transmission ties.

In Europe, hyperbolic concrete cooling towers are frequently employed These large structures utilize natural draft, and permit locating the plan wherever sufficient water for tower makeup and miscellaneous plant uses—usually a few per cent of that required for condensing—can be obtained. A growing number of power plants in this country are using mechanical-draft cooling towers to permit using sites advantageously located with respect to transmission lines, transportation, or terrain. Of those more recently installed, the majority are of the induced-draft type, in which the moisture-laden air is projected upward with sufficient velocity to prevent its recirculation to inlet louvres.

Water from a cooling tower will usually be somewhat warmer than that from a river or lake. Overall efficiency of the plant is further reduced because of power consumption of the circulating fans. These penalties, in high-pressure plants, amount to only two to three per cent of the fuel bill.



The cooling towers are of ferro-concrete. Diameter at the base of the shell is 208 ft., at the top of the shell 128 ft.

As inlet pressure and temperature of steam to turbine increase, less heat must be disposed of in the condenser The regenerative feedwater heater also reduces the condenser load, as steam withdrawn from turbine does not reach the condenser. Consequently, the effect of higher water temperature becomes less important as more efficient cycles are employed, and we may expect increasing utilization of cooling towers

Outdoor Plants

Beginning during the depression, a small number of steam-plant designers began to develop low-cost methods of protecting equipment and personnel against the weather, avoiding the large structures employed generally to house an entire plant Over a dozen such plants have now been built, aggregating more than 500,000 kw capacity, and a number of others, of progressively greater outdoor quality, are now under design (73, 74, 75)

Outdoor substation equipment has, of course, been long in use Some fifteen years ago, a few plants were built with low turbine rooms, having gantry cranes to handle turbine-generator parts through roof hatches About five year later, boilers were placed completely outdoors, except for a steel canopy roof and enclosure around the firing and control room. Later, the turbine-generator was placed on the roof of the condenser room, with or without a removable steel cover Most recent designs omit the housing around the condenser, some employing side condensers to reduce the height of turbine foundation. In these the crane rails are at grade level and close to the sides of the foundation so that a short-span crane can be employed.

Regenerative Cycle

The development of the concept of the theoretical regenerative cycle to replace the Rankine cycle as a basis of computations marks a notable advance Though first suggested over twenty years ago, the heat rate of the newer ideal cycle, which has an infinite number of bleed points heating feedwater from condenser temperature to boiler drum temperature, was difficult to compute. A complete table of such heat rates has now been published, as well as a relatively simple method of solution (76, 77).

Mobile and Packaged Plants

During the war several 30,000-kw. floating power plants were built for delivering power at riverside or tidewater points where local or temporary shortages developed. These plants were erected on barges, to be towed wherever needed. Originally intended only for domestic use, some floaters were reinforced for ocean passage, and were employed in Europe during and after the war (78, 79).

A number of power trains have also been constructed, many for export to Europe. These employ air-cooled condensers, and range in size from 2000 to 10,000-kw. (80, 81, 82).

Complete designs for a 5000-kw power plant are now offered by one manufacturer (83). Several have been sold for use in South America. Another manufacturer offers most of the components for plants of 1000, 2000 or 3000-kw (84).

Controls

Use of combustion control has increased markedly, as coals of poorer quality and higher cost have been burned By-pass control on boiler feed pumps, to assure sufficient flow to carry away heat developed in the pump, has also been widely employed. A novel development is the use of television to carry a view of water level in boiler drum to the operating floor (85).

INTERNAL COMBUSTION ENGINES

Supercharging

One of the most effective ways to increase the output of an internal combustion engine is to raise the pressure of air supply The weight of air that enters each cylinder during a normal cycle is almost directly proportional to its pressure, by increasing the air charged, the fuel charge can also be increased, giving added power output Belt-driven superchargers have long been used in aircraft and automotive applications, in the latter mainly for racing cars

Aircraft engines require supercharging because of the rarified atmosphere encountered at high altitude. Turbines driven by engine exhaust gases are well adapted for driving such superchargers, because as altitude increases, pressure available for expansion increases in the same ratio as the compressor load. Turbo-superchargers were tried experimentally during World War I, but reached their full development only in the recent war, when they were employed in all major types of reciprocating airplane engines (86 to 93).

The larger stationary Diesel engines are now frequently provided with exhaust turbo-superchargers, increasing output for a given cylinder volume by some 60 to 70 per cent While application of the turbo-supercharger to older engines would also theoretically result in greatly increased output, engines not designed for the resulting increased stresses would probably experience high maintenance and rapid wear (94, 95, 96).

Dual-Fuel Engines

The availability of natural gas in the American Southwest and other areas has led to the development of gas engines of large size. Early types employed the Otto cycle, with spark ignition, many smaller units being simply converted gasoline engines. In larger units it has been found worthwhile to take advantage of the higher compression ratio, and hence higher efficiency, that can be employed with the Diesel cycle

At first this was done by injecting the gas into the cylinder in about the same way as in the oil engine. Because natural gas has a high ignition temperature, it was necessary at the same time to inject a small charge of "pilot" oil, to set off the explosion.

A more recent development eliminates the high-pressure gas injector, and at the same time provides exceptional flexibility in burning varying amounts of gas and oil. This consists in mixing gas and air in a mixing valve such as that used with the Otto-type gas engine. Oil is injected, as in the Diesel, at the instant required to ignite the compressed charge. By this means, the proportion of gas fired can be changed at will, in the range of 0 to 95 per cent of total fuel requirement of the engine, by simply turning a valve while the engine is running Or the engine can be run on gas supplied in varying amount, with the controls automatically feeding enough oil to make up the fuel requirements of the engine as determined by the load carried (94, 97).

Air Cooling

The Diesel engine, because of its efficiency and somewhat greater tolerance in fuel quality, has for many years been steadily advancing into the field of the gasoline engine The latter has reigned supreme in the small size range, because of its lower manufacturing cost, lighter weight, and because in most applications fuel cost was not a major factor. The recent development of an air-cooled Diesel engine (98, 99) indicates a further advance into the smaller sizes It is merely noted here parenthetically since there is little likelihood of its application for central electric-power installations

Medium-Speed Plant

Diesel engines employed by utilities and municipal electric systems have almost always been of the heavy-duty, slow-speed type. A report published recently (100) gave results of six years operation of a plant with medium-speed units, indicating the feasibility and possible economy of employing such units for certain types of service

Portable Units

As in the case of steam plants, portable plants in both small and large sizes have been developed The largest is the 6000-kva barge "Electra"; smaller units are mounted on skids (101, 102, 103, 104)

GAS TURBINES

Basic Cycle (Review)

Though much has been published in recent years concerning the gas turbine, there may be a number of engineers to whom the phrase is only vaguely understood Briefly, the gas turbine comprises an air compressor, usually of axial type, and in the simplest units, operating at a pressure ratio of 4 to 1. The air stream emerging from the compressor passes through or around a combustion chamber, where its temperature is raised to 1000 deg. F. or more. The hot compressed air, containing the products of combustion of fuel (from which the name *gas turbine* is derived), then expands through a turbine. The latter develops somewhat more work than is needed to run the compressor, because of the higher temperature. Hence a residual work output is available to turn a generator or deliver mechanical energy

Refinements in the simple cycle begin with a regenerator or heat exchanger in which the heat remaining in the gas exhausted from the turbine is transferred to compressed air before the latter is heated. Further improvement results from breaking the compression and expansion processes into two steps, with a water-tube intercooler between compression stages, and a reheater between turbine stages.

The advantages of the simple unit include small space requirements and simple operation afforded by the omission of extensive heat-transfer surfaces, such as those needed in the steam plant with boiler, superheater, economizer, condenser, feedwater heaters, and so on On the other hand, turbine and compressor are rather large in relation to net output, since they largely cancel each other Moreover, the simple units are less efficient thermally than steam plants. As refinements are added to improve efficiency, the advantage of simplicity is diminished (105, 106).

Swiss Development — Open Cycle

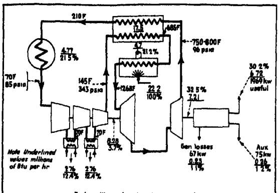
The gas turbine now appears ready to compete with steam in the large power field Most attention has been given to the so-called open cycle, in which air is taken in at normal pressure, and exhaust from turbine is also atmospheric. A 10,000-kw unit has been factory tested in Switzerland and units of up to 27,000 kw are under design there. These will provide the first opportunity to subject the gas turbine to operation of the kind required in electric utility service, for though a 4000-kw unit was installed at Neuchatel, Switzerland, early in the war, it was rarely used because of lack of fuel oil

The 10,000-kw unit mentioned above will be installed in the Filaret station at Bucharest, Romania, where it will serve as standby for water power (107). Low-cost natural gas will be used for fuel, hence a simple unit of relatively low efficiency is employed Size of the unit makes it necessary to use two stages of compression and expansion, so that intercooling and reheat are employed, but there is no regenerator On a factory test using fuel oil (gas fuel being unavailable at the factory), the unit developed 21 per cent thermal efficiency, figured, according to American practice, on high heat value of the fuel. A unit of similar size for Lima, Peru, will employ a more efficient cycle, with regeneration, since expensive fuel oil will be burned

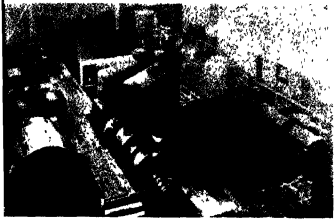
A number of units rated 1500 to 4000 kw are on order for utility and industrial service (108). Two large units are to be employed at Beznau, Switzerland, as standby to hydroelectric systems during winter months when low temperatures keep water frozen and reduce run-off. A 13,000-kw unit will be in all essential respects identical with the Lima machine, the higher rating being due to lower temperature of the air entering the compressors. The other Beznau unit will be rated 27,000 kw, it is the largest gas-turbine unit yet to be atttempted (109, 110).

Swiss Development — Closed Cycle

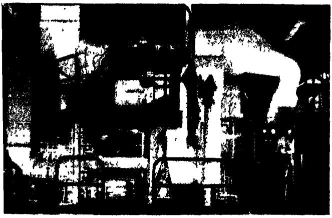
All the units mentioned above have been purchased from one company, Brown Boveri Limited, of Baden, Switzerland. Two other Swiss companies are concentrating development work on closed-cycle gas turbine units, in which the main body of working fluid remains above atmospheric pressure throughout the process. Sulzer Brothers, of Winterthur, Switzerland, have undertaken to build a 20,000-kw unit of this type for a



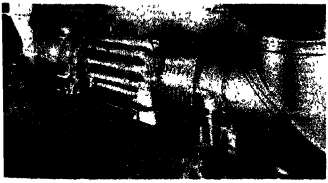
Escher Wyss closed cycle power unit
Heat balance simulated from incomplete full-load test data



The 10,000 kw gas turbine for Filaret Station, Bucharest, is being put through test run in the factory of Brown Boveri.



2,000 hp gas turbine generator being proved at Westinghouse. Silencers are mounted on inlet and exhaust to reduce noise.

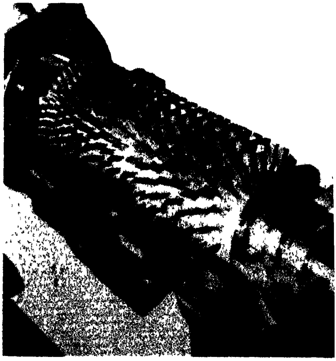


2,500 hp gas turbine under construction for test runs at the Elliott shop. For use in liberty-type freighters.

Swiss utility company (111, 112) Sulzer's work has been with a semi-closed cycle, in which the fuel is burned directly in the working fluid Products of combustion are removed by dividing the air stream, one part of which serves as primary air for the fuel burner, the other passing around the combustion chamber, where it is heated by transfer through metal walls The flue-gas steam passes through a turbine that turns the compressor supplying fresh air to the cycle, and is open to the atmosphere at the exhaust The indirectly heated air stream runs the load turbine, which also drives the main compressor

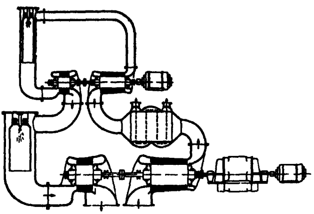
A third company, Escher-Wyss, located at Zurich, Switzerland, has developed a completely closed cycle, in which air or any other gas, such as helium, may be heated through a metal surface Gas exhausted from the turbine is cooled, still under considerable pressure, by means of water, also through a metal surface, after which it returns to the compressor and repeats the cycle. This system loses much of the simplicity of the open cycle, but it is claimed by the manufacturer that heat transfer can be effected in smaller and lighter apparatus than the boilers and condensers required in steam plants Feedwater treatment, scaling, corrosion and carry-over troubles are also eliminated

A 2000-kw experimental unit has been set up at the Escher Wyss factory, under test it showed efficiency comparable with some of the most advanced steam plants, which are of course much larger in size A 12,500 kw unit is now under development, if successful it will probably be offered for commercial application Eventually, however, it is thought that the main field for this cycle, with its relatively high unit manufacturing cost, would be for machines perhaps 50,000 to 100,000 kw in size, operating on a base load of expensive coal fuel This capacity range cannot be attained by single open-cycle units under present day limitations (113 to 116).



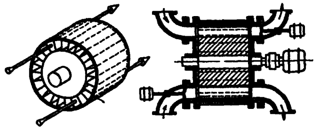
Compressor rotor of gas turbine is shown on cylinder base. Rotating blades are forged and pitched by spacer pieces.

DIAGRAM OF TWO STAGE GAS TURBINE SET



In the two-stage combustion turbine the first turbine produces compressed air only and has no net output. With 1100 deg. F. before each stage, the compressors take 60 per cent of the power produced by the two gas turbines.

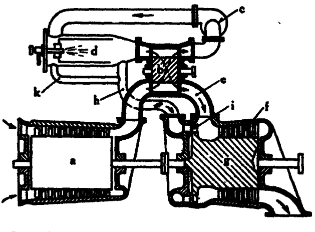
OPERATING DIAGRAM OF COMPREX



CELL ROTOR AND DIAGRAM, COMPREX.

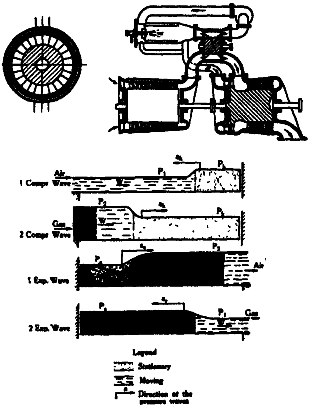
The Comprex consists of a number of cells arranged around a shaft. These cells alternately carry air to be compressed and gas to be expanded; both flow in the same direction as shown in the diagram below which represents the second stage or comprex of the gas turbine

COMPREX AS HIGH-PRESSURE STAGE OF A GAS TURBINE

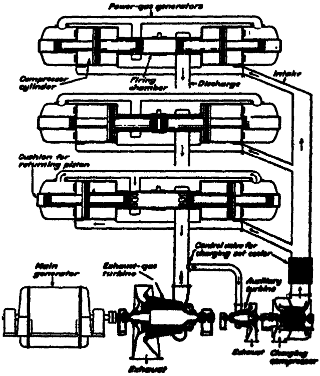


Atmospheric air enters the axial compressor a, is compressed, and flows to the lower part of comprex b, where it enters the cells which, by rotation, bring it to the upper part and compresses it to a higher pressure on the way. It is then blown into a combustion chamber d by blower c, from where it flows into the cell of the comprex, which at the time is on the top, and helps to force the fresh air into blower c. The gases are then brought down to the exhaust e of the comprex and are expanded on the way in such a manner that they help to compress the fresh air. They then enter the reaction part f of gas turbine g where they expand to atmospheric pressure, doing useful work.

OPERATING DIAGRAM OF COMPREX



THREE SULZER FLOATING PISTON ENGINES WITH GAS TURBINE



The three Sulzer floating-piston engines combined with two axial compressors give a net output of 7,000 hp. With a possible overall efficiency of 48 per cent. it represents highest efficiency so far obtained from gas-turbine set and at least 5 per cent higher than the Brown Boveri two-stage 27,000 kw set designed for a Swiss Power Station. Locomotive gas turbine with comprex added increased the efficiency from 17 to 21 per cent.

Comprex

A device recently developed by Brown Boveri, known as the "comprex", has been so far applied only in an experimental locomotive unit, but is potentially important in the stationary power field By this means the energy available in heat at temperatures higher than the maximum at which turbine-blade materials will stand can be utilized The device is a rotating pressure exchanger, consisting of a cylinder with tubular passages arranged spirally about its periphery Low-pressure and hot high-pressure gas enter each passage successively at one end and leave successively at the opposite end In the passageway, compression waves travel back and forth at the velocity of sound. By careful timing of port openings, through accurate control of speed of rotation, the slugs of air leave at high pressure, and those of gas at low pressure Intermixture of air with gas is relatively slight Overall efficiency is 69 per cent, equivalent to a turbine-compressor combination in which each element operates at 83 per cent efficiency

Because the walls of the passageways are subjected to the high temperature of the gas only intermittently, and are cooled in between by the relatively cold air, the gas can be heated to about 2100 deg. F, compared with 1100 to 1300 deg. F commonly employed in gas turbines Since gas has a greater specific volume than the air, an excess remains, this quantity is mixed with sufficient high-pressure air to reduce its temperature to a level safe for the turbine. It then passes to a high-pressure stage of the latter, and so increases shaft output. This increase, which is obtained without correspondingly increasing the work of compression, results in an increase in net work output and in fuel efficiency The comprex itself is free-floating, rotated by a small auxiliary motor.

A locomotive unit, similar in size to the 2200-hp machine built some years ago for Swiss Federal Railways, developed 4000 hp with the comprex added. Its efficiency was also increased from 17 per cent to 21 per cent (109, 117, 118)

Marine Development

Because large power plants for ship propulsion and stationary central-station type power plants have in the past followed roughly parallel courses, it is not improper to discuss here the gas turbines designed primarily for marine use. A small installation is being made in Great Britain to act in parallel with Diesel engines (119). Other units under construction are intended to serve as main propulsion plants.

One of these is a 7000-hp power-gas generator plant under construction by Sulzer Brothers (120). The power-gas generator consists of an opposed-piston Diesel driving a piston-type air compressor to supercharge its own combustion air. With zero net output for this combination, exhaust from the Diesel cylinder can be delivered at high pressure and temperature. This gas expanded through a gas turbine is connected only with the useful load. Overall efficiency is reported about 40 per cent, or higher than has been achieved by any commercial heat-power installation made to date.

Another unit is under construction by the Elliott Company of Jeannette, Pennsylvania This 2500-hp open-cycle unit, to be installed in a Liberty-type freighter, drives a reversible-pitch propeller through reduction gears Difficulty in procuring a suitable shop has held up this work, and it is expected that it will not be ready for testing until some time this year (121)

An Elliott experimental unit was tested under Navy supervision in 1945 (122 to 125) The new unit is substantially the same, with certain improvements. Two stages of compression and expansion are employed, with inter-cooler, reheater, and regenerator The compressors are of the Lysholm positive-displacement type (126, 127, 128), having two cylinders, with interlocking spiral lobes rotating in opposite directions Efficiency is somewhat lower at rated speed than for the axial type, but it remains near maximum value over a broader speed range It has a distinct advantage from this point of view for all variable-speed propulsion applications, but would not be employed in a constant-speed unit, for driving an alternating-current electric generator.

A 3500-hp experimental unit designed and built by Allis-Charlmers Manufacturing Company has been tested by the Navy at Annapolis (129 to 132). Operation was carried out with temperature gradually increased to 1500 deg F, the design point No report of efficiency attained has, to the writer's knowledge, been published.

Locomotive Applications

A number of oil-fired gas turbines are to be built for locomotive use. Great Western Railway of England has two on order from Brown Boveri (133) and Metropolitan-Vickers (134) respectively In the United States, Elliott Company is supplying the power plant for a Baldwin locomotive for the Santa Fe (135), while Union Pacific is adapting a Northrop-Hendy aviation unit for locomotive use (136).

Potentially the most important project under way, particularly as regards its ultimate application in stationary power plants, is the coal-fired gas-turbine locomotive being worked out by Locomotive Development Committee (137 to 140). Coal would be pulverized in a novel manner, by being carried in a stream of com-

Locomotive gas turbine with comprex added

pressed air through a nozzle (141). The rapid drop in pressure causes the air held in internal passages of the coal particles to expand rapidly, shattering the pieces Air and powdered coal will then be burned in the pressurized combustion chamber of a gas-turbine set The high-temperature stream will be put through a series of cyclone separators to remove flyash, before passing through the turbine.

Two experimental coal-fired locomotives are to be built, the power units to be furnished by Elliott Company and Allis-Chalmers Manufacturing Company, respectively. Both units will develop 3750 hp and employ similar cycles, but the Allis-Chalmers will employ more stages of blading in compressor and turbine, giving slightly higher efficiency, along with greater weight and greater volume (141)

Status of New Development

So far the gas turbine has had its largest field of application for the jet propulsion of airplanes. Some work has also been done with gas turbines driving propellers, and with combination of propeller and jet These applications, though of great general interest, are far afield from stationary power applications, and will therefore not be discussed in this issue of THE INTERNATIONAL INDUSTRY YEARBOOK

Large steam turbine manufacturers in many countries are far behind in filling orders for conventional power-generating equipment, and are unable to devote considerable manpower or shop space to new development work. Experimental units for shop tests have been built by several companies These are all simple open-cycle units designed primarily for locomotive use, but readily adaptable for stationary service (142 to 146).

An interesting cycle, if for no other reason than because of its complexity, is under development in France (147). This is the Mercier "Equipressure" cycle. Internal-combustion engines are employed to supercharge air in four cylinders; the first to supply the driving engines, and the remaining three, in series, to produce air at 1200 to 1400 lbs. per sq. in High-pressure air is heated in an airheater and it then supports combustion of fuel (liquid or solid) in a pressurized boiler The cycle is named *equipressure* because gas and steam are produced in this boiler at the same pressure The gas is then expanded in a gas turbine, and the steam in a steam turbine on the same shaft. (148 to 161).

The feedwater cycle begins with condensate being employed in the compressor intercoolers, next, two bleed heaters are inserted, after which the water passes through the engine exhaust jacket and airheater jacket to a third bleed heater Part of the feedwater is flashed following passage through the exhaust jacket; this flashed steam is superheated in a coil inserted in the airheater, then enters a low-pressure stage of the steam turbine. Engine exhaust, after releasing part of its heat in the airheater, enters a low-pressure stage of the gas turbine. The major advantage of the cycle is the wider range of fuels that can be employed, compared with other high-efficiency types of plant; some light oil is, however, required for the supercharging engines.

HYDROELECTRIC STATIONS

No matter what extreme of pressure, temperature or velocity the steam plant designer may employ, he cannot capture public imagination in anywhere near the same degree as the hydroelectric engineer There is something about the mass, the individuality, and often the physical beauty of a water-power development that cannot fail to arouse interest While the steam man takes pride in the compactness of his design, and its flexibility for reproduction with moderate adaptation under a variety of geographical conditions, the hydraulic engineer is compelled by circumstances to quote quantities in millions of cubic yards, billions of gallons or hundreds of square miles, and to develop designs based on the peculiarities of a particular site

One of the most recent, and by far the most staggering, of these speculations is for a gigantic development on the Yangtze River at Ichang Gorge (162, 163, 164). The dam will be the world's highest and most massive, and the power plant will ultimately develop more than 10 million kilowatts—sufficient at 50 per cent capacity factor to about equal the 1946 consumption of electric power in all Great Britain.

A fourth dam on the lower Colorado River in Arizona is planned to go 118 miles above Hoover Dam, at Bridge Canyon (165) The arch-gravity dam will be 736 ft high, and the power installation, consisting of six 125,000 kva generators rated 560 ft head and 180 rpm, will be housed in a cavity inside the dam.

An interesting case is the hydro development at Lake Sevan in Armenia (166) Because of dry atmosphere, high altitude (7000 ft.) and small inflow, the entire inflow to the lake is normally evaporated from the 600 sq mile surface. In order to obtain power output from the outflow to the Zanga River, the lake level will be lowered 175 ft, to reduce the surface from which evaporation can take place—thus reversing the normal procedure of raising level to increase head.

In a number of countries where fuel resources are lacking or undeveloped, and transportation facilities meager, the principal means to improved living standards lie in developing hydroelectric resources to provide power for industry. This is the case in China, as mentioned above, as well as in India (167), Mexico (168), and Egypt (169)

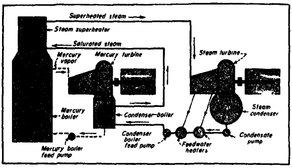
Important hydro developments are being made in Canada (170, 171, 172) and in Switzerland (173) Pumped storage has been used to a moderate extent in Swiss developments (173, 174.). The Federal Power Commission of the United States has completed a hydro survey of southeastern Alaska (175), and plans for development of the Missouri Basin have been formulated (176 to 182).

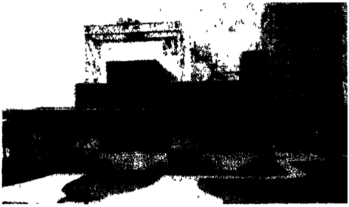
MISCELLANEOUS PRIME MOVERS

Mercury Plants

The mercury-steam binary vapor cycle has been developed over the past twenty years in three full-size installations at Schenectady, New York, Hartford, Connecticut, and Kearny, New Jersey. These are among

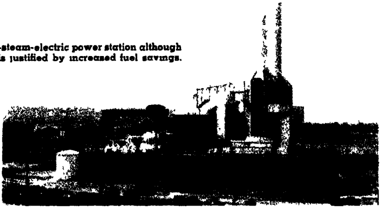
Diagram illustrating the mercury-steam cycle





Semi-outdoor steam electric station of 30,000 kva put into service in 1947 for Arkansas Power and Light Company.

This outdoor mercury-steam-electric power station although of initial higher cost is justified by increased fuel savings.



the most efficient heat engines now in existence, surpassing all but the most modern steam-turbine units in regular operation. Under test conditions they compare favorably with the best in Diesel engines.

Several standard-design mercury units have been offered by the General Electric Company, rated 5000, 7500 and 15,000 kw. In addition to electric output, the units produce steam at high pressure and temperature, that can be used to supply existing steam turbines, providing a topping installation with high efficiency. The first of these units will be installed at the Company's plant in Pittsfield, Massachusetts, and another installation will be made at Portsmouth, New Hampshire.

Solar Energy

Elementary textbooks on physics customarily point out the enormous amount of energy in solar radiation. For example, on one square mile of horizontal surface, at noon in mid-summer, there would be incident sufficient energy to produce, at 100 per cent conversion efficiency, about 2,000,000 kw. Thus the energy absorbed at the surface of a large reservoir is many times greater than that developed by passing the contents of the reservoir through water wheels. The difficulty of concentrating solar energy at a temperature sufficiently high to permit generation of even moderate amounts of power, prevents utilization of this remarkable potential source of power.

At the Tashkent cannery in Siberia, Russian engineers have built the first solar power plant designed for industrial use. Parabolic mirrors 80 meters in diameter are used to focus the radiation, and are said to produce steam at pressures and temperatures suitable for power generation (183, 184).

Wind Turbines

The first wind turbine to produce energy for a large interconnected power system was completed in 1941 at Grandpa's Knob, Vermont. The 100 kw unit, which had a two-bladed propeller of 165-ft total span, operated successfully for several years, with an amount of maintenance not excessive, in view of its experimental nature. During 1945, however, a particularly heavy wind broke off one of the blades, and the unit has not yet been returned to service. A new plant of twice the capacity has, however, been designed, and it is planned that this will be installed at a suitable location in Vermont (185 to 188).

GENERATORS

Hydrogen Cooling

Nearly all large high-speed generators are now cooled by hydrogen gas in a closed system, the hydrogen being recooled in surface-type raw-water heat exchangers. Newer machines are designed for 15 lbs. per sq. in. gage hydrogen pressure, thus permitting about 16 per cent increase in kva rating for carrying peak loads with low power factor. *AIEE-ASME Preferred Standards* specify hydrogen cooling for units 20,000 kw and up, but non-standard units as small as 15,000 kw have been built with this system.

Hydrogen gas has much higher heat capacity per unit of weight than air, thus offsetting its low density for effectiveness as a heat transfer medium. The low density results in low windage loss, improving generator efficiency. The improved cooling that results is an important factor in permitting the increase in speed of very large generators from 1800 to 3600 rpm (189, 190). Liquid cooling of generators has even been suggested (191).

High Speed

With alternating current used almost universally, speed of rotation of a generator is limited by the frequency employed. For many years the largest steam-turbine driven generators were of 4-pole design, rotating at 1800 rpm to produce 60-cycle current, or 1500 rpm where 50 cycles was standard Two-pole machines, running at 3600 and 3000 rpm, respectively, were employed in smaller machines, the maximum size increasing rapidly as designs were improved

One of the problems encountered in the two-pole design was the so-called double-frequency vibration Rotors of two-pole machines are normally rigid in only one plane, whereas those of four-pole machines are rigid in two planes The major improvement made to reduce vibration was achieved by slotting the rotor to reduce rigidity in the plane of the poles, in order to equalize conditions with respect to the other plane (189, 190). Generators up to 100,000 kw. capacity are now being built to run at 3600 rpm

Excitation

The standard method of excitation for power generators is the direct-connected excitation generator, which in turn is excited by means of a direct-connected pilot exciter Some development work has been done with electronic exciters, that is, vacuum tube rectifiers, particularly at Springdale Station of West Penn Power Company (192, 193, 194).

Illustrations for this chapter were obtained through the courtesy of the United States Atomic Energy Commission, Federal Power Commission for Natural Gas Investigation, American Society of Mechanical Engineers, American Institute of Electrical Engineers, Westinghouse Electric Corp., General Electric Co , Allis-Chalmers Manufacturing Co., Brown Boveri Corp., Elliott Co , Escher Wyss, British Information Services, and Worthington Pump & Machinery Corp

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CHAPTER XXIV

RAILROADS

by ROBERT S. HENRY

Railroads are constantly engaged in research in all phases of transport activity Exposed as most of the railroad plant is to constant wear in hard service, to the unceasing action of weather and the elements, to extremes of temperature, and to emergency requirements which constitute an unavoidable part of all transportation, railway employees unendingly search for improvements in materials, techniques and procedures—whether or not they think of these activities as research. The results are given the acid test of service in locomotive and car shops, and on the right-of-way, through careful and painstaking comparison of the quality and service life of the new device as compared with that which it is intended to replace.

Changes Are Gradual

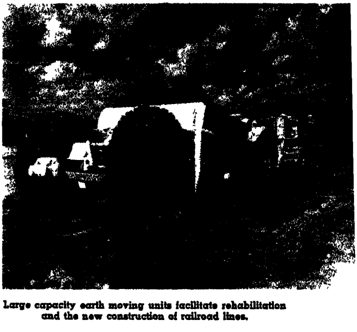
So complex is a railroad that major changes must be made gradually and with due recognition of the effect upon other operations A freight-car coupler, for example, cannot be changed without considering how the new device will work, during the necessary period of transition, with every other one of the nearly 2,000,000 freight cars in service Similar considerations apply to many other features of the standard and interchangeable freight cars which are so largely responsible for the continental character of American commerce

In other aspects of railroading, the repercussions of even seemingly simple changes are still wider To replace one form of motive power with another, for example, involves detailed investigation of its effect on many interrelated activities: enginemen are given new training, roundhouses and division shops are often rebuilt or re-equipped with new and different tools, shop crews are trained in maintaining the new motive power. New fuel supply facilities also may have to be provided, turntables enlarged and strengthened, train schedules revised, and passing sidings, turnouts and switches rebuilt, lengthened or relocated. The effect of the new locomotives on bridges, structures, track, ties and roadbed must be studied. Even accounting procedures relating to depreciation and maintenance practices may have to be re-studied and possibly adjusted to the characteristics of the new power. Advertising, public relations, and the activities of suppliers, as well as personnel problems, may all be changed The disposition of the displaced motive power must also be considered; if it is moved to other divisions of the railroad, it will in turn affect operations elsewhere. All these and other related considerations must be evaluated and the necessary changes fitted into the normal operations of the railroad.

Because of these complex inter-relationships, changes on the railroads may seem to take place more gradually than in some other industries Each device must be considered in relation to all other factors of operation, and must operate in complete harmony with older but similar equipment, or else it must be modified, introduced in a different fashion, or withheld until a more propitious time (1)

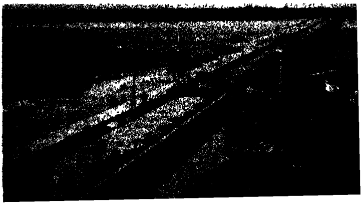
Track

Track determines a large part of the technical operating and traffic procedures and problems of a railroad Track has three main functions, simple to define but hard to achieve It must support the load, provide



Large capacity earth moving units facilitate rehabilitation and the new construction of railroad lines.

View of the International Bridge connecting Uruguay, Brazil and Argentina. Provision is made for railroads and a highway.



a smooth surface for easy movement, and guide the wheels of the train Good track starts with the roadbed, or foundation Extensive experimentation on a cooperative basis has been applied to roadway and ballast problems, including those of drainage, stabilization by piling or concrete grouting, and waterproofing of ballast (2, 3)

There are a billion and a quarter ties in the tracks of American railroads, and approximately 45 million of them are replaced each year because of decay or mechanical wear. In many places, ties which have been installed for 25 to 30 years are still giving good service With modern methods of chemical treatment, decay has been greatly reduced, and mechanical wear from the impact of loads transmitted through the rail now is more serious as a cause of replacement To reduce this wear, metal tie plates are inserted between the rail and the tie

The present shape and weight of rail have evolved gradually to meet operating needs It was found by research and test that increasing the height of a given rail from 7 in. to 7¾ in, without any change in the weight per yard, would bring about an increase of approximately 14 per cent in the vertical stiffness of the rail Similarly, a change in design, with an increase in weight from 130 to 131 lbs per yd, added as much as 10 per cent to the ability of the rail to resist lateral deflection.

Large-scale ballast cleaning train cleans both shoulders of the track simultaneously at a rate of 2½ track miles per hour.

Discovery and prevention of internal defects called transverse fissures, which might lead to a broken rail, have made great progress

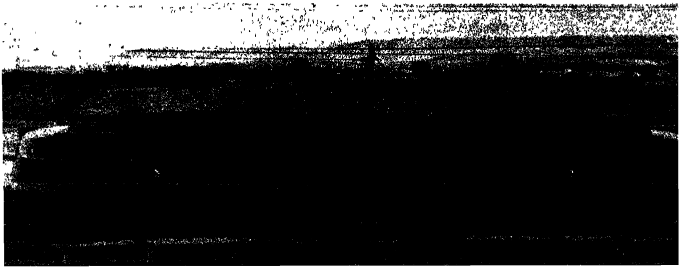
The pounding of heavy locomotives and cars at high speed batters the ends of the rail after a period of time. To reduce maintenance and replacement costs, railroad maintenance engineers have developed various methods of building up the battered ends by welding Another approach has been to develop continuous-welded rail, on the principle that longer rail means fewer joints or rail ends at which batter can occur (4 to 8)

Research attention also has been focused upon rail fastenings, which include track bolts, spring washers, spikes, tie plates, rail anchors and joint bars. Frogs and switches have been the subject of a joint project between makers and engineering committees Other subjects of research analysis include the economics and methods of grade revision, curvature reduction, line changes, the rolling resistance of trains at various speeds, and the development of dynamometer cars for road testing of trains (9).

Mechanization of Roadway Maintenance

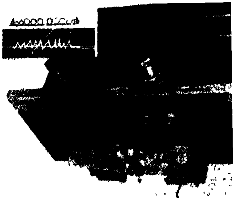
Maintenance-of-way work has become increasingly mechanized for greater productivity and economy. The railroads now have in use large numbers of track motor cars, rail cranes, spike pullers, adzing machines, bolt tighteners, spike drivers, power tampers, tamping machines, ballast cleaners, ballast plows, rail oilers, ditching machines, bulldozers, power shovels, weed burners, weed mowers, power rail drills, power rail saws, power augers, and power wood saws Many of the larger items of track machinery are now self-propelled and work from alongside—instead of on—the track, thus avoiding interference with train movements and at the same time

Largest single-cab, heavy-duty electric locomotive is used for mountain traffic; 101 ft. long, powered by 12-axle mounted traction motors, it has a rating of 5,000 rail hp.



Close-up of a thermit pressure weld.

Transverse fissure in rail was discovered by the Sperry Detector before complete fracture of rail occurred.



Machine attached to bottom of rail registers on metal plate the load applied by each wheel. Record is shown (above left) of electric locomotive moving 100 miles per hour. Magnification is 100 X.

saving part of the costs associated with the use of "work trains" (10, 11)

The more than 190,000 bridges of various materials on the railroads have been obvious subjects for research Special attention has been paid to impact stresses and their effect upon bridge design, adaptation of welding to construction and maintenance, and use of reinforced concrete structures and ballasted-deck bridges After a bridge is built, it frequently happens that newer types of locomotives and cars come into use, setting up greater stresses and strains. The bridge then must be strengthened, or else train operation must be restricted as to weight or speed, to keep the stresses within safe limits Magnetic strain gauges, recently developed, now are in use for measuring electrically the precise stress sustained by bridges under varying types of impacts and loads

Technical problems in welding bridges are being overcome, resulting in lighter and cheaper structures, with lower maintenance costs Use of aluminum for bridge construction also is in the direction of lighter structures (12 to 16).

Communications (17 to 23)

Trains cannot be run speedily, safely, and dependably without good communications The far-flung nature of railroad plant and organization also requires good communication for managerial coordination and control of operations

The telephone and telegraph systems of railroads have become closely interrelated, especially since it has become practicable to use the same wires for both telephone and telegraph circuits It is now possible for the same group of wires to carry two dispatching circuits between train-order offices; several message circuits leading to freight houses, yard offices, passenger ticket offices, and other points; a so-called *overhead* system for messages and conversations; and teletypewriter circuits.

In recent years, technological development has made it possible to utilize radio on the railroads As a result of knowledge gained from experimental installations, radio can be advantageously used, under the proper conditions, in the following ways:

1) End-to-end train communication—between engine or caboose and conductor, or other employee on the ground, and between one train and another train when approaching or passing each other.

2) Fixed point and train—for yard operation and between a dispatcher or other fixed point and a moving train (including emergency situations where communication is desirable between a central point and a derrick snow plow, fire-fighting apparatus, or the like).

3) Emergency service to bridge gaps in communications when wire lines are down as a result of flood, storm, or accident

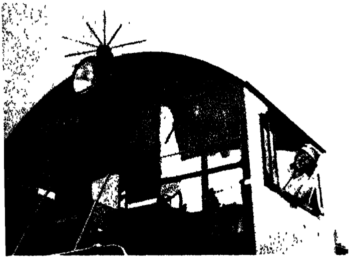
4) Remote direction and control of train operations in areas where centralized traffic control systems (described in the next section) are used, a similar use would be found on electrified railroads where radio could control power circuits and speed up rearrangements of supply in the event of failures

Many technical obstacles yet remain to be overcome, but the use of radio in railroad communications is bound to grow and to play an important part in railroad operations

Extensive experiments also are being conducted by railroads in the use of radar, which was so largely developed for many wartime uses While public discussion has emphasized the possibility of application of radar and similar warning devices to trains, these discussions

Control tower showing switch and retarder controls for a hump yard.

View of locomotive cab showing engineer talking over radio. On the wall of cab is shown radio control box and speaker.



Engineers in switching engine received train orders by radio. Antenna of mobile transmitter-receiver is mounted on roof.

Dispatcher's office showing Central Traffic Control Apparatus covering 121 miles of track.

often evidence lack of a full understanding of the principles involved in reflected-beam electronic devices There also are important physical differences between using such devices on an aircraft above the earth's surface, or a ship at sea, with free radio access to any point on the surface within range of its radio equipment, and their use on a surface vehicle passing roadside obstructions, and threading around curves, through hills or tunnels, and across bridges.

While experimentation with variations of radar devices will continue and may finally produce useful and applicable results, such accomplishment will depend upon satisfying railway signal engineers as to the suitability and dependability of such devices for railway use under all operating conditions One of the present adaptations of radar which shows considerable promise of development for use by railroads is for speeding up, with safety, the operation of tugboats used in connection with railroad car-ferries in large port cities such as New York

Signals (24 to 30)

Signals are analogous in function to communications, but have a more specific function—they are addressed only to employees in charge of trains, and especially to the locomotive engineer, to inform him about the track ahead

With automatic block systems, the train itself operates the signals which protect it The key to the system is the track circuit, a weak electric current flowing through the rails

New methods of transmitting electrical impulses have increased the flexibility and efficiency of block-signal systems With the use of "coded circuits," signals can give five indications, clear—proceed, three degrees of caution, and stop. Thus, it is possible to give the engineman information on conditions three blocks ahead, ample time to comply with the indication. In some cases, there are five-indication signals covering the situation four blocks ahead.

Cab signals, located on a panel in the locomotive cab facing the engineer, are now used on many lines to supplement or replace signal indications on a pole or mast beside the track.

Further in connection with the use of block-signal systems, automatic train-control devices are effectively used in some situations. Different methods have been adopted, but their common purpose is stop a train automatically if it should pass a signal set against it. By use of an "acknowledger," the engineman can forestall the operation of the automatic stop by pushing a lever to signify his awareness of the fact that the signal indication is against him.

Where tracks cross, automatic interlockings are extensively used to increase safety and reduce costs. In these devices, switches, locks, and signals are so interconnected that their movements must follow each other in predetermined order, thus insuring that conflicting movements cannot take place. The interlocking mechanism may function either electrically or mechanically.

Interlocking devices not only provide positive protection at track crossings but also eliminate the necessity for many train stops, either to see if the crossing is clear, or to wait for another train to clear it. Compared with manual operation, automatic installations eliminate the need for a central machine and other appliances, as well as for attendants to operate the levers.

A similar device, for the same purposes and also based upon the automatic-interlocking principle, is the *entrance-exit* (or NX) mechanism, which has been installed in many large passenger and freight terminals, and other localities where movements are made through an intricate track layout. With the entrance-exit installation, the operator presses a button for the track on which the layout is to be entered and another for the track of exit. The mechanism then automatically selects the proper route of movement through the layout, sets all the switches and signals involved, and locks them against any conflicting movement. The locks are released as the movement clears various points on the route.

In addition to these and other signaling techniques to improve train operation, it is now possible by means of *centralized traffic control* (or CTC) to direct train movements entirely by remote control. Orders to train crews are not needed. Instead, switches and signals over many miles of line are controlled by a single operator, sitting before a panel or switchboard in a control room. Before him, the position of each train is shown automatically on an illuminated diagram of the line. Below the diagram are knobs which govern each signal and small levers which govern each switch on the line. By his exact knowledge of where trains are, the operator can arrange closer meets between opposing trains as well as faster *run-arounds* of slow trains by fast ones at the nearest siding. Non-stop meets of opposing trains on single track are a common occurrence where CTC is installed.

Track capacity is increased under CTC operation by as much as 50 to 100 per cent. This increase often postpones or eliminates the expense of multiple tracking. In addition, costs are cut through the reduction of train stops, safety is enhanced, and train speeds are increased. In some cases, where grades at the entrance to sidings restrict the engine load, CTC may permit the running of heavier trains because stops on the grade are eliminated. This is also accomplished in some cases by use of individual remote-control switches. Changes in desired train movements can be made more quickly, safely, smoothly and efficiently with CTC than by any alternative system available.

Engines and Cars

Engines and cars and facilities for maintaining and servicing them are fundamental to the operation of railway transportation service.

Passenger cars (31 to 44): There is much more to a passenger car than meets the eye of the ordinary traveler. The electrical system, for example, offers many problems. The present electrical system of the car, in addition to lighting, supplies power for fans, ventilators, electric shavers and—most important—air conditioning. While the primary objective of the equipment is to enhance the comfort and convenience of passengers, the design also must be such as to require a minimum of upkeep and repair and, if repairs are called for, to promote their speedy accomplishment, so that cars can be kept moving.

Despite their apparent simplicity, passenger-car wheels offer many problems. Wheel wear is a subject of much complexity, and new facts about it are being learned all the time. One important fact that must always be taken into account is that rolling on the rails is not the only function of the wheel. It also must support the load of the car and contents (about 140,000 lbs). It must also transmit the braking forces to the rail. Because conditions vary, there are different types of wheels, of varying metallurgical composition and adapted to different operating conditions.

The axle involves metallurgical and engineering problems similar to those involved in the wheels, and new designs are being evolved to reduce fatigue failures. By the use of tubular instead of solid axles, weight is reduced and greater strength obtained in relation to actual weight of metal.

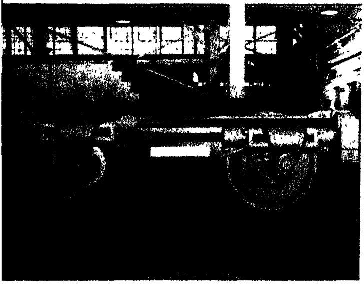
All the developments brought about in tracks, motive power, and other plant facilities to promote greater speeds of train operation would be of little avail without a correspondingly developed braking system for trains, because safety demands adequate brake control at all times.

The railroads meet the problem of braking with the automatic air brake. Each car has such brakes, which are actuated by air pressure from the engine. Compressed air from the locomotive is distributed to reservoirs on each car, through air hoses which connect all cars. Each car has a control valve, which sets the brakes when there is a reduction in the air pressure from the engine.

Automatic slack-adjusters keep the slack in the brake rigging uniform throughout the train and thus equalize brake tension. Wheel-slip protectors and speed-pressure regulators automatically adjust the application of braking force as the train speed is reduced. The *decelostat* electric generator, which regulates brake pressure, is constantly being improved to permit greater refinement in the proper adjustment of braking force. Wheel-slide controllers on individual axles release and reapply brakes when a pair of wheels is about to slide. Develop-

Modern, heavy-duty machine tools reduce costs of repair and maintenance, assuring more efficient operation.

Machine for testing track under conditions simulating rolling traffic.



Torsion-spring freight "truck" is being tested to improve riding, increase speed, reduce cargo damage and wear and tear on rails. It is intended to reduce side-to-side movement and impact shocks.

The "truck" for a Santa Fe freight diesel-electric locomotive.

ments are constantly being made in brake shoes to save wheel and shoe expense.

These are but a few of the items of equipment beneath the passenger-car floor. Much might also be said about springs, center sills, draft gears, tightlock couplers, piping, and so forth Their design, construction, inspection and maintenance are under continual study and improvement

Freight Cars (45 to 52) Freight cars have become increasingly specialized to meet the changing demands of an increasingly specialized economy While the variety of cars provides better service to industry, it also increases the complexity of the car-supply and maintenance problems of the railroads

Fortunately, however, much of the maintenance problem has been eased by standardizing the cars from the floor down—the working parts Wheels, axles, frames and springs, couplings, draft gear, and brakes—all have been standardized The development and general adoption by the railroads of a code of rules to govern the interchange of cars and their movement and repair on "foreign" lines (that is, lines other than their own) has been a major achievement

Many items of the trucks and running gear of passenger cars have their counterparts on freight cars, in some instances with modifications to take account of differences in the characteristics of the two kinds of service

Braking control follows the same general principles for freight as for passenger trains, but with modifications in detail The application of the AB brake system for freight train cars poses many new problems. Each car now has two reservoirs—one for ordinary brake applications and one for emergency use Technical obstacles have been solved so that it is now possible to follow a service application of the brakes with an emergency application, or to slow down to very low speed, then release the brakes and pick up speed The AB freight brake, due to the very quick propagation time of a brake application, enables smooth stops, free of shocks and run-in of slack, on trains up to 150 cars or more in length.

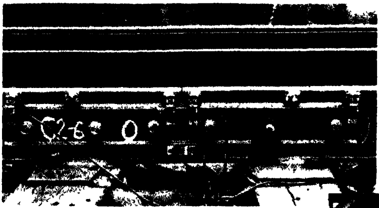
Back of the coupler of the freight car, and connecting it to the center sill or principal structural member of the car, is a device called the draft gear In a space about two feet long, with an end area of less than one square foot, the draft gear must absorb the shock of coupling loaded cars which may weigh up to perhaps 75 tons or more, with a recoil of no more than 2¾ in. Improvements are being worked on which will make the draft gear still more flexible in responding to light blows and yet having greater ability to absorb heavy blows and thus diminish shock to the car itself.

Lighter weight of freight car trucks is an important goal which is gradually being achieved. Lighter materials for side frames, bolsters, brake beams, and so forth serves to reduce weight.

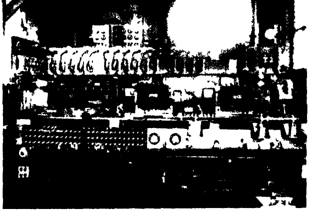
The truck springs are vital to smooth riding of the car body and load. Improved springs and snubbers are means of achieving greater stability. As with draft gear, the problem is one of shock absorption.

Shop Facilities

With all the mechanical equipment on approximately



An example of research by American railroads: Special measuring devices are installed under sections of track to register performance under actual traffic. A section of track under tests is shown at left. Wiring shown on left runs to the testing mechanism shown below.



2,000,000 freight cars (counting privately owned and all other units), 46,000 passenger-train cars (including diners, mail and baggage, etc), plus 88,000 cars for company service needs, it is obvious that car maintenance is a tremendous undertaking

During the war the importance of the car shops was brought home forcefully By working longer, harder, and better, shops drastically cut the number of "bad order' cars out of service awaiting repairs This reduction was equivalent to adding about 175,000 cars to the active supply (53, 54)

Locomotives (55 to 69)

The locomotive has undergone many changes. Today's engines develop 6,000 horsepower or more, and are capable of hauling up to 10,000 or more tons in a trainload They may be propelled by steam, electricity or internal combustion, and may be fueled by coal, oil, or gasoline

To reach this stage development, many new devices first had to be introduced. For instance, by superheating steam inside the boiler, without increasing the pressure, the temperature can be brought up to 700 deg. or more, instead of the previous maximum of around 375 deg The automatic stoker feeds coal in the quantity needed to keep the proper fire over the entire grate area of the locomotive. Boilers, flues, valves, grates, pistons, cylinders, and so on have been improved as new materials and new designs became available

Roller bearings permit easier starts and increase the availability of locomotives Welded boilers reduce both weight and maintenance cost. With the improvements made in foundry practice, the entire frame of the locomotive now can be cast as one huge, integral part, solving important technical problems. Automatic oilers provide lubrication to the multitude of working parts Booster engines, working through gears on the trailing axles, give added tractive power for starting and for slow-speed operation. Arch pipes, circulators, and siphons installed in the firebox promote water circulation in the boiler and increase heating surface. Feedwater heaters draw heat from otherwise-wasted exhaust steam and use it to preheat the water passing from the tender to the boiler.

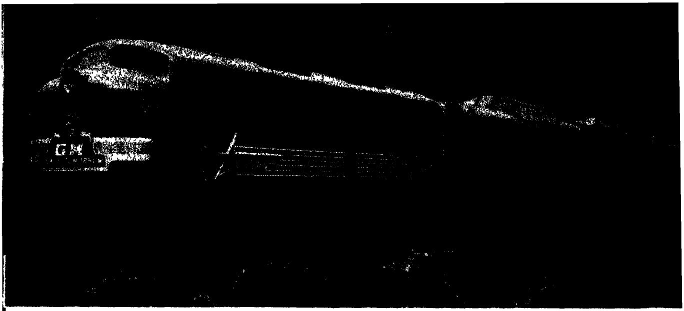
Changes such as these have greatly increased the type and amount of the work output of the locomotive. The work done by a freight train in one hour has more than doubled in the last 25 years.

Improvements for one purpose often bring problems in some other direction. Virtually all water contains some natural impurities, some of which are adverse to efficient locomotive operation Modern railway operation calls for great quantities of water, high temperature, large and complex evaporating systems, etc Consequently, much attention has been focused on the solution of this difficulty by the use of chemicals added to the water, water-softening plants, automatic blow-off systems, and so on Experimental installations have been made with ion-exchange resins, which remove calcium and carbonate materials and provide water approaching the quality of distilled water

From the standpoint both of public good will and of economy in operation, railroad mechanical departments have been exploring methods for eliminating smoke through more efficient combustion. Overfire air jets have helped Better designs for air passages are under study, and other ideas are constantly being investigated

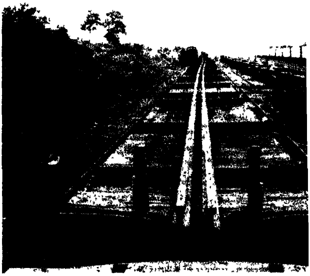
New Types of Coal-Burning Locomotives: In recent years, steam turbine locomotives have been developed which promise to overcome some of the difficulties in the conventional reciprocating steam engine. More recently a coal-burning gas turbine has been brought to an advanced stage of experimental development. A *coal atomizer* using compressed air breaks up the coal into fine powder. This powder is burned under pressure to produce a very hot gas, which drives the turbine.

Electric Locomotives: The initial cost of electrification is high, but operating cost is low. Hence, electrification is most advantageous when traffic volume is heavy, and electrified trackage tends to be located mostly in areas of dense traffic. Recent developments of electric locomotives have taken the form of larger and more powerful units.



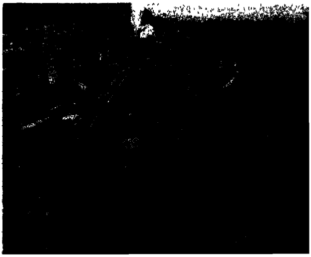
Newly completed "Train of Tomorrow" embodies advancements in design and mechanical operation. Built to permit practical tests of any new ideas, it includes glass-enclosed observation roofs and floor space on four levels.

Looking down into the engine pit of a diesel engine maintenance shop.

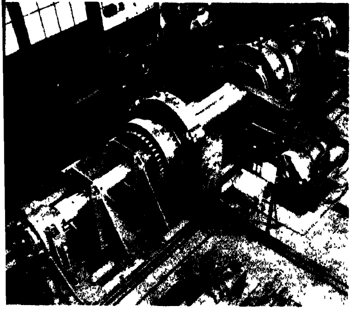


Continuous welded rails on flat cars in yard ready for transporting to section of track being laid.

Car retarders at key interchange points speed classification of freight cars. This yard handles 3,000 cars daily.



Railroad research laboratory on wheels is capable of recording speed, engine pull and wide variety of technical data on locomotive performance.



Axle testing machine at the Timken Roller Bearing Co.'s plant.

A steam turbine locomotive test plant to determine operating conditions.

Diesel Locomotives· The great difficulty in applying diesel power to railroads was the need for intermediate drive The reciprocating steam engine drives the wheels directly, with the power controlled through the amount of steam admitted to the cylinders to drive the pistons. By contrast, the diesel engine requires a transmission arrangement to vary the power supply from a high level in starting to a low level at full running. Mechanical, hydraulic, and pneumatic methods of transmission have been used, especially on smaller units, but most diesels now in use have an electric transmission; the diesel engine drives a generator, which produces electricity to run electric motors, which turn the wheels.

The first cost of the diesel locomotive, and the costs of the lubricants and fuel used are relatively high. For these reasons, plus the fact that many railway operations do not lend themselves to the intensive locomotive utilization and high mileage needed to justify the cost of a diesel, the introduction of diesel power has not meant its wholesale substitution for steam power. If continued technological development fulfills its promise, the steam locomotive will continue to give the diesel real competition in certain fields of operation (56 to 69)

Locomotive Maintenance

The operation of locomotive shops involves a number of problems like those of any heavy manufacturing industry Powerful cranes and hoists are needed, along with furnaces, tanks, grinders, presses, milling machines, steam hammers, punches, shears, pipe forges and cutters, and many other types of tools and equipment.

As diesel locomotives came into more widespread use, there was need for special facilities to service them. Today there are numerous diesel terminals, where a wide range of services are performed (some of which also are common to steam locomotives (70 to 72)

Yards and Terminals (73 to 84)

Yards and terminals are key points of the railroad system From, to, and through them flow, and in them are serviced, assembled, and classified, the cars and locomotives Their importance as factors in efficient operation cannot be overestimated.

In a hump yard, gravity does much of the work of switching A humping engines moves an entire freight train upgrade to the top of the hump at constant speed, usually 2 to 4 miles per hour Working from the switching list, a crew member uncouples one or more cars at the summit, and gravity carries them onto the classification tracks The selection of tracks is controlled by power switches, operated from one or more control towers at strategic points in the yard

In some earlier installations of hump yards, cars moving down the hump to classification tracks were controlled by car riders, who had to be returned to the hump, either on foot or by riding a motor car. A great improvement on this type of operation is the installation of car retarders. The retarder is a braking device, located along the track, which clasps each side of the car wheel at the rim. It is actuated from the control tower. With the combination of retarders and power switches, the operators in these towers control both the direction and speed of car movement by pressing a series of buttons or switches.

In large cities, certain of the yard facilities applying to freight operations also have their counterparts, as appropriate and needed, for passenger operations. Examples are storage tracks, cleaning tracks, and turn-around tracks for passenger cars, and commissaries, with adjacent tracks for the supply of dining cars. At large stations, there also will be tracks for loading and unloading mail and express

Changes are being made affecting passenger terminals and service Stops for high-speed trains are reduced wherever possible. Increasing cost of passenger equipment makes it important to expedite the turn-around of cars after each run, even at some additional cost in men and equipment, the primary purpose being to produce greater frequency of service while reducing congestion at main terminals and using rolling stock to better advantage Mechanical equipment to handle baggage, express, and mail is coming into increased use. Terminal buildings are being improved and modernized Ticket machines and other devices to speed up ticket sales are well advanced in development In these and many other ways, service to the passenger is in process of substantial improvement

Welding operator builds up frog by the oxy-acetylene process.

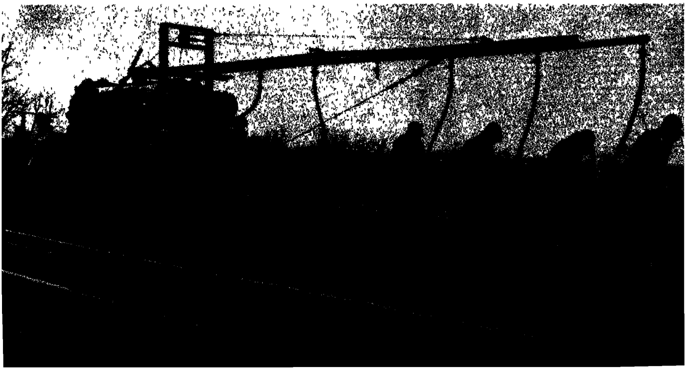
Loading and transfer stations for handling less-than-carload freight are being further mechanized, and freight handling reorganized to do the job more quickly and efficiently Pallets are increasingly being used for many types of packages

Improvements in Yard Operation (85 to 88) In recent years, railroads have adopted a number of improvements in yard operation Summary descriptions of a few of these will serve to illustrate the nature of the changes and their significance to railroad operation.

Servicing locomotives is at best a time-consuming process Several steps have been taken to reduce these delays and thus increase the utilization of equipment. These include the provision of new facilities to speed up the supply of fuel, water, and sand (for better traction) In addition, track changes have been made, to speed up movement of engines to and from the enginehouse without interfering with other terminal operations

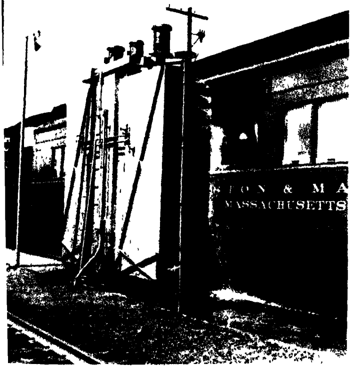
Safety first is a basic tenet in all railroad operations. At virtually all yards and terminals and at all points of interchange between railroads, inspectors go up and down the length of each train looking for defects in wheels, axles, brakes, journals or other car parts. To

Pneumatic spike drivers represent various improvements in maintenance and construction equipment to save time and manpower, and lower costs.



Modernized Chicago, Burlington and Quincy Railroad Station.

A dining car going through final exterior washing.



speed up inspection without sacrificing safety, sunken pits have been installed, usually on the main track into the receiving yard, where inspectors are stationed, flanked by a battery of floodlights Cars are checked from the pits as the train moves at slow speed into the yard.

In many cases railroads have found it economical to substitute diesel switching locomotives, despite their somewhat higher initial cost These units can carry two to four days' supply of fuel oil, and can be refueled quickly They require only periodical inspection, and there is a long time span between necessary overhauls On the average a diesel unit displaces about 1.4 steam switchers For these reasons there has been a definite trend toward dieselizing yards

A basic problem in the operation of a freight classification yard is that of keeping under supervisory control a wide range of activities conducted by a large staff moving from point to point over a wide area Telephones, of course, are in general use, but there are many occasions when yard forces are not near a telephone or other fixed communication facility Consequently, a number of other devices and methods have been developed, including two-way radio communication, with resulting gains in yard efficiency (85 to 88)

Ordinarily, when a train arrives at the receiving track in the yard, there is considerable clerical work to be done in connection with its cars In recent years some roads in areas of heavy traffic have replaced or expedited this work by adopting various mechanical systems involving the use of punch cards (such as are used in electric tabulating machines) combined, through a recent technical development, with the use of teletype equipment While such installations as yet are largely in the experimental stage, with new uses for the punch-card data still being explored, there seems no doubt that such systems promise considerable increases in economy and efficiency in many situations

The use of photography for copying waybills and other documents essential to train operation also has expedited train movement by reducing time needed for clerical work (89 to 92)

CHALLENGE TO INGENUITY

Facing severe competition for traffic, the railroads are exercising their utmost ingenuity, not only to hold unit costs of operation to a minimum while advancing service standards, but to develop and perpetuate the railroad industry as the nation's greatest public servant and the bulwark of private enterprise One avenue of doing so is through the development and use of all devices and practices that lend themselves to this accomplishment.

Illustrations for this chapter were obtained through the courtesy of Caterpillar Tractor Co., Administracion General de Vialidad Nacional (Uruguay), Great Northern Railway, Delaware & Hudson Railway, Baltimore & Ohio Railway, St. Louis Southwestern Railway, Southern Pacific, Association of American Railroads, American Welding and Manufacturing Co., Santa Fe Railway, General Motors Corp., Standard Oil Co. (N J.), Central Railroad Company of New Jersey, Norfolk & Western Railway, Pennsylvania Railroad, Oxweld Railroad Service Co., Chicago, Burlington & Quincy Railroad, and Boston and Maine Railroad.

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CHAPTER XXV

RUBBER

by HARRY L. FISHER

The impact of the war on the rubber industry was enormous The plantations were occupied by the enemy, ocean transportation was practically stopped, and this country had to turn to synthetic rubber to put its mechanized army into the field, its naval craft into the water and its planes into the air. The result of cooperation of technical men and manufacturers in producing the required materials is history, but only recently has the publication of the very important scientific and technologic work made it possible for the world to know what was behind it all and how it was accomplished

GR-S (Government Rubber–Styrene type), the all-purpose synthetic rubber, took the place of natural rubber during and just after the war (1). The call is still for more of the synthetic GR-S even though almost as much natural rubber was imported into the United States in the first half of 1947 as was imported during the entire previous year, namely, approximately 400,000 long tons. Other synthetic rubbers, although in much less tonnage, played very important parts too

Commercial synthetic rubber was first produced in the United States in 1930 but the production in 1940 amounted to only about 4,000 long tons For the 820,373 long tons produced in 1945, large amounts of many different materials had to be obtained, shipped to the proper locations where the synthetic rubber plants had been built, and then the final products reacted to give synthetic rubbers.

General Statements and Comparisons

It must be remembered that natural rubber, or more definitely the natural rubber hydrocarbon, has never been synthesized, so far as known, and the term "synthetic rubber" appears, therefore, to be a misnomer However, the term is justified because "rubber" is now also considered as the name of a type of material instead of only a chemical individual.

No one rubber, natural or synthetic, fulfills all the requirements placed on rubberlike materials or elastomers. Some synthetic rubbers are doing yeoman service where natural rubber could not be used at all, and some give services for long periods of time and under conditions where natural rubber would have to be replaced frequently.

Stretching and rapid return after release are the unique characteristics of all rubbers. They can be stretched from about two to ten times their original length, and will return rapidly to approximately their original length when the stress has ben removed. They have high energy storage when thus stretched, that is, they show low hysteresis loss and low heat buildup (2). They show durability under repeated stress cycles, resistance to abrasion (3), good electrical insulation properties, chemical inertness to a remarkable degree, and moderate-to-high impermeability to moisture and gases

Vulcanized compounds of natural rubber, Neoprene, Butyl and Vistanex show the greatest elongations, although even these can be compounded to give very low elongations GR-S, the nitrile rubbers, Butyl and Thikol require the admixture of carbon black or certain resins to bring out their best properties Statements about rubber must always be qualified because of the variations possible with each rubber and with each particular form of a specific type

None of the rubbers equals natural rubber in low heat buildup under repeated stress and that is why natural rubber is so good in tire carcass stocks and especially in large sizes of tires like those used on buses and trucks Passengar car tires made entirely of GR-S are almost as good as those made from natural rubber and often show even greater resistance to abrasion, but bus and truck tires containing GR-S must also contain at least 30 per cent of natural rubber in order to keep the heat buildup low

Foamed latex is poured into a mold after the latex is whipped full of tiny air bubbles.

Publication of War Work

A great deal of the important scientific research and technological development work done on synthetic rubbers and the materials used in them, during and just after the war, has been appearing in the journals but publication is still far behind. Some of these papers are discussed below and others are included in the bibliography for the sake of completeness.

Natural Rubber

Considerable thought is being given to the preparation of natural rubber. More uniform and satisfactory types of rubber could probably be developed by careful attention to methods of coagulation (4). Another author writes that more thought should be given to develop rubber having better inherent qualities (5). Fractionation of latex should produce graded qualities, copolymerization of the rubber and olefins should make rubber with interesting modified properties, and proper methods of coagulation should control the amounts and proportions of nonrubber constituents and thus make for greater uniformity of the plasticity. Also, tree selection should develop rubber that has a higher average molecular weight and chain length, and thus improve the qualities that are already superior to those of synthetic rubbers.

Work is also being done on natural rubber from sources other than *Hevea brasiliensis*, namely, from *Ficus elastica* (6) and milkweed (7). Also, guayule rubber extracted by the Jordan-type mill contains less acetone-benzene insolubles than that obtained by the pebble mill and its vulcanites show superior properties (8).

Natural rubber latex is being received in the United States (9) but it has strong competition from the synthetic latices (10, 11). Improvements have been made in storing latex that make it possible to preserve it for three to five years by keeping it free from bacteria and sufficiently alkaline and with a uniform total of solids as well as maintaining properly regulated temperatures and minimum exposure to oxygen (12). Also, a method has been developed for producing machined wet sheet within three minutes after acidification of latex provided the latex has previously been treated with a saturated long straight-chain fatty acid (13).

Raw Materials for Synthetic Rubbers

Butadiene has been used in the greatest amount in the manufacture of synthetic rubbers, since it is the chief constituent of GR-S (14). That which was prepared from alcohol was made by passing a mixture of alcohol and acetaldehyde over a heated catalyst consisting of silica gel impregnated with tantalum oxide (15). Furfural is used in the purification of butadiene by the removal of impurities through azeotropic distillation (16). An azeotrope is a mixture of two or more liquid substances which distill at a constant temperature that is different from the boiling points of any of the constituents. Some of the impurities thus removed are unsaturated hydrocarbons, olefins or acetylene derivatives, that retard, some slightly and some very strongly, the copolymerization of butadiene and styrene in the preparation of GR-S and other similar copolymerizations (17, 18).

Under certain conditions, butadiene and styrene, separately or together, form a white cauliflower-like polymer that sometimes causes the bursting of pipes and requires more or less complete reinstallation of equipment in the synthetic rubber factories. The spontaneous formation of this insoluble, infusible, so-called "popcorn" polymer, is initiated in a variety of ways, iron and active oxygen playing important parts (19). By a scientific study of this reaction, it was found that the active centers or seeds can be deactivated by exposure to nitrogen dioxide diluted with air and therefore the initiation of popcorn formation can be completely inhibited (20).

The manufacture of styrene by the Dow process has been described (21). Benzene and ethylene are catalytically combined to make ethylbenzene which is then converted to styrene through the loss of two atoms of hydrogen by means of pyrolysis.

A new furnace carbon black superior to the familiar channel black has been prepared (22). Also, a "white

Synthetic liquid latex is coagulated with alum in a screw conveyor and drops to a disintegrator.

After coagulation and disintegration, synthetic GR-S rubber is baked in a continuous oven.

soot"—fumed silica—has been prepared that gives interesting reinforcing properties (23). In addition, an aqueous dispersion of high purity and finely divided silica of wide application in rubber compounding has been announced (24).

A new silicone oil when compounded in GR-S shows improvement in abrasion resistance especially when lower grades of carbon black are used (25). New incompatible bulky plasticizers soften synthetic rubbers with less care in processing and permit them to retain their molded shapes indefinitely even before vulcanization (26). GR-S and natural rubber can also be plasticized with o,o'diacylaminodiphenyl disulfides (27). The German plasticizer for synthetic rubbers, "Koresin," is an alkyphenol prepared from p-tertiary butylphenol and acetylene (28). Ricinoleate esters give good low temperature properties to nitrile rubbers (29).

New organic vulcanizing agents have been reported: organic compounds having two or three halogen atoms on the same carbon atom (30), and alkyphenol sulfides (31). Butyl rubber can be vulcanized without sulphur by using quinonedioxime and dinitrosobenzene derivates (32).

Synthetic Elastomers

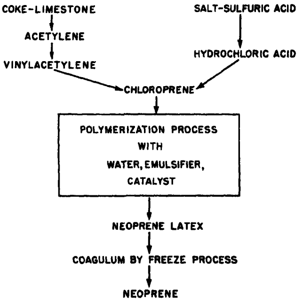
It would take much time and space to discuss each elastomer and its properties and its advantages over other elastomers. However, it seems desirable to give a brief description of each one in order that a rather complete picture of the entire field can be had.

GR-S

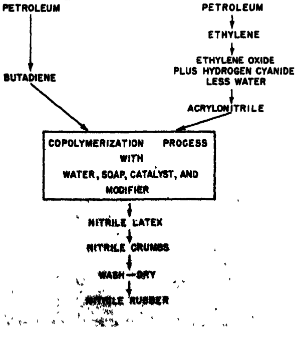
GR-S (Government Rubber-Styrene type) is manufactured almost entirely by the U. S. Government and of all the synthetic rubbers it is still produced in the greatest quantity. It is prepared from about 78 parts of butadiene and 22 of styrene by emulsion polymerization (33, 34). In the emulsion process, the butadiene, which is a gas that boils at 24 deg F., and the liquid styrene are stirred in water containing soap until they are completely emulsified. The water also contains a small amount of potassium persulfate as an initiation of polymerization and of a mercaptan as a modifier of polymerization. The emulsion is carefully stirred and kept at a temperature of about 105 deg F. for 15-17 hours, during which period the main constituents react or copolymerize to about 75 per cent. Greater conversion produces a poorer rubber. A reaction stopper and an antioxidant are then added, the unused butadiene and styrene removed and recovered, the artificial latex is coagulated with a solution of salt and sulphuric acid or of alum and the coagulum washed, dried and baked.

The regular GR-S contains a small percentage of

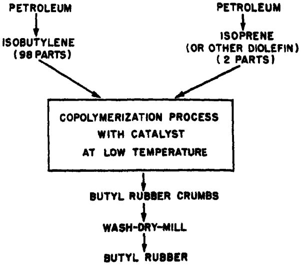
HOW NEOPRENE IS MADE



HOW NITRILE RUBBER IS MADE


PETROLEUM
PETROLEUM
ETHYLENE
ETHYLENE OXIDE PLUS HYDROGEN CYANIDE LESS WATER
BUTADIENE
ACRYLONITRILE
COPOLYMERIZATION PROCESS WITH WATER, SOAP, CATALYST, AND MODIFIER
NITRILE LATEX
NITRILE CRUMBS
WASH—DRY
NITRILE RUBBER

HOW BUTYL RUBBER IS MADE


PETROLEUM
PETROLEUM
ISOBUTYLENE (98 PARTS)
ISOPRENE (OR OTHER DIOLEFIN) (2 PARTS)
COPOLYMERIZATION PROCESS WITH CATALYST AT LOW TEMPERATURE
BUTYL RUBBER CRUMBS
WASH-DRY-MILL
BUTYL RUBBER

salts which, of course, lowers the electrical insulation properties in the presence of water In order to improve these properties, about one per cent of Dixie clay is added during the acid coagulation, this reduces the electrolyte content to a negligible amount with significant improvement in dielectric properties (35)

Master batches of GR-S and carbon black are prepared by adding the black to the latex before coagulation (36) In tire tread stocks, these can be used directly instead of mixing the black in the GR-S on a mill, and the following advantages have been reported reduced mixing time, 5-10 per cent better wear resistance, better crack growth resistance, economy of compounding costs, and increased cleanliness of operation Similar master batches of zinc oxide, clay and silene are also made.

Molded mattress of foam rubber emerges from electronic oven after vulcanization and drying.

GR-S is the general all-purpose synthetic rubber and can be used for at least 90 per cent of the uses of natural rubber It is handled and vulcanized very much like natural rubber Its compounds age well, have good insulation properties, and show very good resistance to both heat and abrasion, but, like natural rubber, are not resistant to swelling by oils and solvents. It normally possesses less tack than natural rubber, but the addition of tackifiers and the use of cements overcome this difficulty

GR-S has also been prepared in the laboratory by the copolymerization of butadiene and styrene in the presence of metallic sodium as the catalyst (37) This sodium GR-S is not as flexible at low temperatures as regular GR-S, but in processing quality and in balance of flex crack growth and hysteresis, it exhibits real advantages (38).

Butadiene and chlorine derivatives of styrene have been copolymerized in the regular emulsion form, and some of the copolymers have been found to be superior to GR-S in tensile strength and flex crack growth (39).

Nitrile Rubbers

Copolymers of butadiene and acrylonitrile, generally known as nitrile rubbers, are made by the emulsion process with proportions varying from 70/30 to 55/45 Their commercial names and the companies that manufacture them are GR-A (Government Rubber-Acrylonitrile type), U S Government, Butaprene N, Firestone, Chemigum N, Goodyear, Hycar OR, Goodrich; Nubun N, U. S Rubber, and Perbunan, Standard Oil Company of New Jersey Like GR-S, they require the addition of carbon black or certain resins to make compounds with the best properties These elastomers have a wide temperature range of usefulness from −70 deg to +300 deg F, a low compression set, low coefficient of friction, excellent heat aging, high abasion resistance, good sunlight resistance, and very good re-

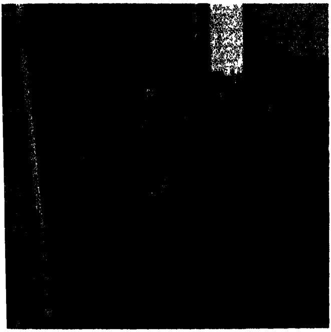
New $2,000,000 laboratory will help Firestone expand program of rubber and plastics research.

sistance to the swelling action of aromatic solvents, naphthenic oils and chlorinated hydrocarbons.

However, the tensile strength of the compounds is lower in comparison with natural rubber compounds, the tear resistance is lower, and the heat buildup is greater The nitrile rubbers are used in a great variety of molded goods, gaskets and hoses, where resistance to oils and solvents, heat and abrasion are required

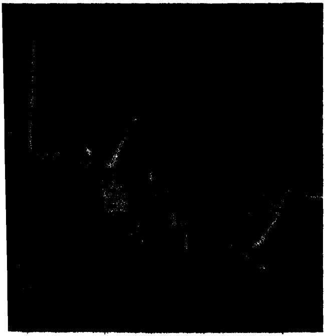
Butyl

Butyl synthetic rubber, also known as GR-I (Government Rubber–Isobutylene type) is manufactured for the government by Standard Oil Co of New Jersey It is a copolymer of a high proportion of isobutylene (C_4H_8) and a low proportion of isoprene in the general ratio of 98/2. The reaction is very different from the emulsion process and is carried out in the presence of a special catalyst at a very low temperature, –60 deg F or even lower. Under similar conditions, isobutylene form polyisobutylene (Vistanex) which is practically saturated and is not vulcanizable, but the addition of the low proportion of isoprene gives enough unsaturation to make Butyl vulcanizable. Conversely, the high proportion of saturation gives

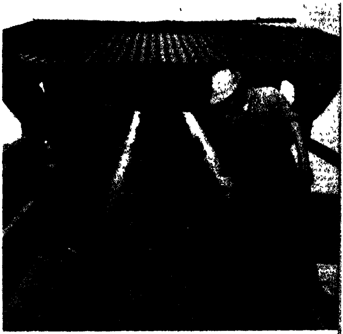


Slab of Chemigum (GR-A), formed from layers of thin sheet, is cut off the winder roll.

Film of Neoprene (GR-M) leaving the "freeze roll" on which it is coagulated at about 14 deg. F.

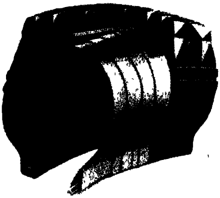


Neoprene sheet is washed, dried and formed into a rope, then cut into short pieces and bagged.



Neoprene covered conveyor belt after ten years' operation; it is more rugged than natural rubber.

Tread design and shape are imparted to tires by vulcanizing molds.



Steel wire is the foundation on which this tire is built; average car tire contains about 140 ft. of wire.

Synthetic rubber tire is tested for heat buildup, operating temperature and wear resistance.

Butyl its unusual resistance to heat, aging, ozone, and the action of strong acids and other corrosive chemicals Its impermeability to gases is the greatest of all the elastomers This interesting property together with its excellent resistance to tearing and abrasion makes for longer-lasting inner tubes (40), curing bags in the vulcanizing of tire casings, and molding bags employed in the manufacture of plywood materials

Neoprene

Neoprene can be considered as a chlorine derivative of polybutadiene, and is prepared by the emulsion polymerization of chloroprene, a chlorobutadiene Instead of being recovered from the latex by the usual acid-salt coagulation, it is coagulated by being frozen by a new and unique process (41) The latex is passed as a film over a cold drum on which it is completely coagulated at a temperature of about 14 deg F The coagulated polymer is moved forward as a film, is washed, dried at 250 deg. F, and then gathered into a continuous "rope", cut into small sections, and bagged

Neoprene is manufactured by E I duPont de Nemours and Co, and also by that company for the U. S Government. It is also known as GR-M (Government Rubber—Monovinylacetylene) It is made in several grades of plasticity, each grade being given a letter or letters. Types GN and GN-A are all-purpose rubbers and the most widely used

Neoprene is more like natural rubber in its general properties than any of the other synthetic rubbers Its pure gum compounds are excellent and require no carbon black to make them useful although carbon black can be used as a reinforcing agent It can be vulcanized by heat alone without the use of sulphur

Its compounds are resilient and elastic, show good resistance to abrasion, and are superior to natural rubber compounds in resistance to oxidation, heat, sunlight, the coronal discharge, and especially the swelling action of oils and solvents Although its compounds do swell somewhat in oils and solvents, the volume increase is low, and they maintain most of their original physical properties even when swelled Neoprene has a high chlorine content, almost 40 per cent, and is practically nonflammable and does not support combustion. When properly compounded, it is useful at temperatures as low as about −60 deg. F. These properties make neoprene useful in a great variety of applications, many of which cannot be filled at all by natural rubber.

Thiokol

Thiokol is the trademark name for products manufactured by the Thiokol Corporation. The Thiokol rubbers are very different in chemical composition than any of the other synthetic rubbers; they are prepared by the interaction of alkylene dichlorides and related dichlorides with sodium polysulfide. They require no sulphur for their vulcanization, only zinc oxide or quinonedioxime (GMF) and zinc oxide. Their remarkable resistance to the action of nearly all solvents, oils, fats and greases make them of particular interest for hose of practically all kinds and for products that come in contact with these materials. They require carbon black for reinforcement and proper handling.

Thiokol Type ST gives stocks that are resistant to cold flow, have good flexibility down to −60 deg. F.

good abrasion resistance, and excellent resistance to sunlight, ultra-violet light, ozone, and the diffusion of gases. In tensile strength and flexibility they are inferior to natural rubber compounds.

These materials are also available as molding powders, hot spray powders, and liquid polymers.

Polyisobutylene

Polyisobutylene (Vistanex, Standard Oil Co of New Jersey) is odorless, tasteless, nontoxic, and also nonvulcanizable. It is produced in several varieties which have different average molecular weights. Vistanex is especially useful in mixtures of other elastomers, waxes, resins and asphalt to improve them by adding special properties of increased aging, resistance to flex-cracking and cut-growth, improved electrical properties, and lower impermeability to gases. With paraffin wax they make hot melt adhesives and paper coatings that are flexible at low temperatures and more impervious to moisture than ordinary wax coatings.

Silicone Rubbers

The silicone rubbers (General Electric) or silastics (Dow-Corning) have silicon and oxygen instead of carbon in the polymer chain. They are remarkable for their properties of withstanding not only low but also very high temperatures, −70 deg to +520 deg F (42), of resisting the action of air, ozone, and many corrosive chemicals. A test sample after 90 days in air at 300 deg F was still good, GR-S cracked after 1 day (43). They also provide good electrical insulation. They are used for gaskets for high temperature equipment, such as diesel engines, gas turbines, air compressors, radial engine motors, jet engines, and in a new type of oil seal that operates around high speed shafts at temperatures of 350 deg to 400 deg F.

Synthetic Resinous Types

In the emulsion copolymerization of butadiene and styrene, as the proportion of butadiene is decreased

Coagulated Thiokol pellets in hopper ready for further processing; coagulation takes place in the vat.

Thiokol remains flexible under extremely low temperatures; it is resistant to solvents, oils, and sunlight.

Firestone's new research laboratory employs its complete machine shop to custom build special research equipment.

and that of the styrene is increased beyond the 50.50 ratio, the product becomes stiffer and less rubberlike until around 25 parts of butadiene and 75 of styrene, the products are resinous These resinous copolymers are compatible with GR-S and also with natural rubber giving improved processing characteristics to the mixtures and making compounds that have greater hardness and stiffness than the original rubber, greater resistance to abrasion in spite of increased hardness, and outstanding resistance to flex cracking (44, 45) Similar reinforcement properties have been obtained for some years in natural rubber by the use of cyclized rubber Certain phenolic resins also give similar properties with natural rubber, GR-S, and the nitrile rubbers (44, 46, 47) Polyvinyl chloride and a nitrile rubber form interesting resins that act as non-migratroy plasticizers in rubber stocks (44, 48)

Finally, there are the new S-polymers prepared by the copolymerization of styrene and isobutylene by the low-temperature technique similar to that used for making Butyl rubber (44, 49). Combined with natural and synthetic rubbers, they improve processability and water vapor and gas impermeability.

Hard Rubber

Hard rubber types can be made from GR-S and the nitrile rubbers but not from neoprene and Butyl rubber (50, 51, 52, 53) GR-S hard rubbers have electrical properties superior to natural rubber ebonite because the compositions contain lower proportions of electrolytes The nitrile rubbers give excellent hard rubbers that are superior in impact strength and high temperature service (52, 54) The new resins mentioned in the preceding section are also of interest in the preparation of useful hard rubbers

Reclaimed Rubber

Reclaimed rubber helped much in many applications to conserve natural rubber early in the war and while

Partial view of government owned synthetic rubber plant. Butadiene and styrene tank depot is in foreground.

Calendering a self-supporting film for Perbunan-vinyl compound on a rubber mill.

Laboratory ball mill for grinding pigments used in compounding experimental rubbers. Jars turn on rubber rollers.

GR-S was coming into production. The question of making reclaims from articles containing more or less GR-S and other synthetic rubbers has been solved, chiefly by the use of proper solvents with some modifications of regular technique (55, 56) Its quality is excellent

Illustrations for this chapter appear through the courtesy of Firestone Tire and Rubber Co, Monsanto Chemical Co, Goodyear Tire and Rubber Co, E. I du Pont de Nemours & Co, Thiokol Corp, American Iron and Steel Institute, and U. S Rubber Co

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CHAPTER XXVI

STANDARDIZATION

by HOWARD COONLEY

It should be pointed out that no single article can adequately describe the tremendous work being done in the field of standardization by organizations in the United States and other countries of the world. So many organizations are engaged in this work and so much work has been done that only the high spots can be briefly mentioned in the space which can be allocated to it here. For this reason, Mr. Howard Coonley has limited his paper to a mention of those organizations and technical societies in the United States which have carried on standardization work as one of their major activities. Many organizations and companies cannot even be mentioned despite the fact that they have made significant contributions to standardization practices. In subsequent issues of THE INTERNATIONAL INDUSTRY YEARBOOK greater detail can be devoted to annual developments, employing this article as a general reference on the broader aspects of progress to the present.

EDITOR.

Today standardization is recognized throughout the world as the underlying principle of mass production; as a stabilizer of costs in a period of rising prices (1); as a tool for management to eliminate the necessity of making repeated decisions. It makes it possible to keep machinery running without unnecessary delays through the use of interchangeable parts; and it is the process through which the needs of the user of a product are geared to those of the manufacturer (2). Standardization has played an influential part in developing the labor-saving, high-efficiency industrial processes of today (3).

Standards are of many different types, all of them intended to provide a uniform basis for clear understanding between manufacturer, distributor, and user, between executives, technicians, and shop (4). They cover: (a) *Nomenclature,* such as definitions of technical terms used in specifications and in contracts, and in technical literature; abbreviations; letter symbols for quantities used in equations and formulas; graphical symbols (ideographs or pictographs) used on drawings, schematic diagrams, and the like. (b) *Uniformity* in dimensions necessary to secure interchangeability of parts and supplies, and the interworking of apparatus. (c) *Specifications* for quality of materials and products. (d) *Methods of test* for materials and products. (e) *Ratings of machinery and apparatus* which establish test limits under specified conditions as a basis of purchase specifications, or which establish requirements as to performance, durability, safety, etc., under operation. (f) *Provisions for safety* of workers engaged in production or for use of machinery and equipment (g) *Standard processes and operations* for industrial establishments. (h) Standards providing for *concentration upon the optimum number of types, sizes, and grades* of manufactured products

Not only are standards of different *types* but they are of different *classes* (5). There are standards that are prepared by individual companies for use in their own organization or with their suppliers. There are standards prepared by societies and associations for use among members of their own group There are also standards prepared by groups of national organizations for use as national standards, and finally there are agreements reached on the international level

Standardization Before World War II

Before World War I, there were about 400 organizations in the U S. which had some standardization activities. The professional engineering societies were among the more prominent groups doing standardization work. There was little or no cooperation between groups or coordination of their work. During World War I, the greatly increased demands on industry proved that coordination was needed As a result, a coordinating organization, known at that time as the American Engineering Standards Committee and now the American Standards Association, was set up Its work was based on the principle that national standards should reflect the needs of all groups concerned and, to be of the maximum use, must be developed through the cooperation of all these groups (6) The application of this principle soon brought into the organization many associations and societies and even government departments. The development of safety standards (needed in connection with the administration of factory regulations) brought in insurance companies, state labor officials, safety organizations, as well as representatives of employers and employees, and manufacturers of industrial machines (7).

From 1920 to 1941, when Pearl Harbor brought the United States into World War II, these groups and many others, including the Army, Navy, and other departments of the Federal Government, worked on an expanding program of national standards in many fields—mechanical, electrical, safety, building, highway traffic, consumer goods, photography, gas appliances, and mining. How greatly the standardization program in the United States has expanded is shown in a recent report of just one organization engaged in standardization work, the American Society for Testing Materials, which called attention to the fact that there were 28 ASTM standards in 1910; more than 500 in 1930; and more than 1,000 in 1947 (8).

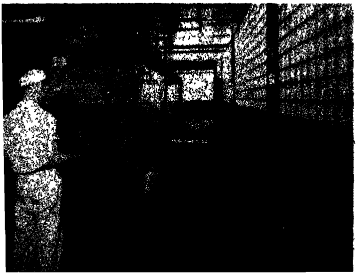
Standardization and World War II

World War II further accelerated the growth of the standardization work and emphasized its importance to the country's economy. Coordination of standards between industries was even more important than it had been in peacetime, and shortages of essential materials coupled with the severe performance requirements of the Armed Forces, made unprecedented demands on the coordinating machinery of standardization during World War II. Many stories have been told of the losses in men and material due to the lack of standards. There is the story of the battleship that returned 600 miles to a supply base for a needed repair part only to find that there was a part aboard which could have been used if it could have been identified as the right size and fit (9, 10) There are stories of tons of spare parts of different makes accumulated at supply bases while equipment damaged in battle remained out of use because a part for a particular make was missing. There are stories of battles lost in the desert because standard tests for radio parts had failed to take into account the effect of the terrific heat and sand erosion.

All the technical societies and associations which had been working on standards before the war put their facilities at the disposal of the government. They worked closely with the Conservation Division of the War Production Board which correlated the standards and specifications of industry with the requirements of the Armed Forces and put them into effect as WPB orders.

One of the wartime standardization programs developed through the War Production Board which is having an effect on post-war techniques is the development of the National Emergency Steel Specifications. These specifications, prepared through the cooperative efforts of the American Iron and Steel Institute, the American Society for Testing Materials, and the Society of Automotive Engineers, among others, represent an entirely new approach to the specification of grades and qualities of steel, since they specified not only the composition of the material but also the heat treatment and other processes in manufacture. This technique, it was found, could provide steel of similar performance characteristics with different combinations of materials

Approval of new safety code will benefit bakery equipment manufacturers through the elimination of conflicting state regulations.



In addition to standard tests and specifications for materials and equipment, the requirements of the war gave an impetus to the development of standards for consumer goods and for the protection of workers. The scarcity of materials, for example, made it necessary for the War Production Board to allocate materials for necessary work clothing and safety equipment on the basis of standards which would make the best use of the materials available.

International cooperation was also given added impetus during the war (11). The close coordination of the activities of the various national armies under General Eisenhower accentuated the difficulties caused by differences in the equipment and parts produced by the United States and Great Britain. Out of the attempts to reach agreements on standards has come the official recognition of the importance of standardization in agreements between the Chiefs of Staff of Great Britain and the United States, and between the United States and Latin American countries (12)

International Organization for Standardization

During the past year the international organization of national standardizing associations has again been activated and the International Organization for Standardization has been set up (13, 14). The national associations of 26 countries are members. Headquarters of the Association are in Geneva, Switzerland. 64 projects for international cooperation have been agreed upon including such post-war problems as definitions, nomenclature, and specifications in all science and engineering fields and in the field of ultimate consumer goods. American industry is being asked by other countries to take a leading part in this international cooperation, since other countries are looking to the United States for technical leadership. Through agreements among themselves, the countries that are members of the British Commonwealth of Nations are sending material about their standards in early stages to the United States for comment and criticism by whatever companies in the United States may be interested in them.

The International Organization for Standardization will coordinate its work with the standardization programs of other international organizations. The International Electrochemical Commission (15), which has 40 years of experience in voluntary international standardizing for the electrical industry, has made arrangements to become the electrical division of the ISO, while keeping its individual name and methods of operating.

A looser relationship than that with the IEC has been established by the International Labor Organization (16) and the International Civil Aviation Organization (17) with the International Organization for Standardization A committee is now studying methods for developing cooperative arrangements with these two organizations and with the International Federation for Documentation, International Dairy Federation and the United Nations Educational, Scientific, and Cultural Organization

The International Labor Office is carrying on a long-term program of safety standards for the protection of workers and has under way a Model Safety Code for Factories for the guidance of devastated countries which are rebuilding their industries and for countries which are developing new industries It makes recommendations for safety in the planning, layout, and construction of plants, and the installation and operation of machinery and processes in factories

The International Civil Aviation Organization is working on standard procedures and operating practices and on the facilities necessary for international air navigation Its main goal is safety It is anticipated that the material and manufacturing specifications which may be developed through the work of the International Organization for Standardization and which may bear a relation to the needs of ICAO can be correlated with the procedural and operating standards of ICAO.

American Standards for control of quality through the use of statistics widely put into effect by the Ordnance Department during the war have been adopted in many countries (18, 19). One of the foremost American authorities on the subject went to India recently to help the newly organized national standardization association there put it into use.

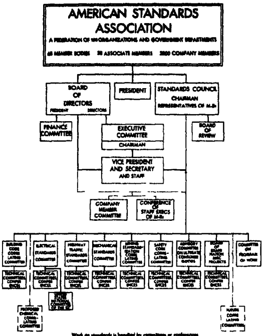
Benefits of Standardization

The question of the legality of standardization under the anti-trust laws of the United States has been given serious consideration It is the opinion of lawyers who have studied the problem that the procedure of the American Standards Association in which all parties at interest are represented in the development of a standard gives an American Standard a legal standing which makes it difficult to attack (20, 21, 22).

The ultimate effectiveness of any standardization program is dependent upon how standards are used in the companies which are manufacturing or purchasing the equipment, machinery, or component parts for which the standards have been prepared (23, 24, 25). Since World War II, strongly accentuated interest in standardization has been noticeable among the companies themselves. One evidence of this is the Company Member Committee of the American Standards Association, through which standards engineers of ASA company members come together. The active interest and work of this committee during the past two years have had a definite influence on the work of standardization committees operating under the procedures of ASA. The needs of the companies for specific standards are brought directly to the attention of the committee, and through this contact some of the problems of the committees are better understood by the groups which eventually must use the product of their work. Uniform drawing practice, standard methods of measuring the roughness of machined surfaces, standard designations for sheet metal, and screw threads are among the subjects in which they have shown special interest recently

The post-war importance of standardization to industry in facilitating the manufacture of a better product at a lower cost is also reflected in the organization of the company standards departments Recently, the General Electric Company made its standards department a division of the Executive Department and gave it responsibility for coordinating standardization throughout all General Electric plants A study of company organization for standardization by the National Industrial Conference Board, however, shows that only one-third of the 93 companies covered by the report have formal standards organizations Companies with strong standards organizations reported to the Board that one of the chief benefits to them of industrial standardizing is to reconcile the differing interests of engineers, production men, purchasing officials, and sales executives "For example, designers frequently have a tendency to keep tolerances close," the report explains "When the manufacturing men receive the drawing they may find that the expense and effort required to meet such a tolerance are exorbitant It may turn out that the part in quesiton does not require a finish of the specified tolerance Meanwhile, much time and expense has been involved Effective standardization prevents this by establishing appropriate standard tolerances in line with performance requirements for the product"

One of the most widely discussed standards is that for drawing and drafting room practice. It is estimated that nationally uniform practice would save industry and government thousands of dollars.


AMERICAN STANDARDS ASSOCIATION
A FEDERATION OF ORGANIZATIONS AND GOVERNMENT DEPARTMENTS
MEMBER BODIES
ASSOCIATE MEMBERS
COMPANY MEMBERS
BOARD OF DIRECTORS
PRESIDENT
DIRECTORS
PRESIDENT
STANDARDS COUNCIL
CHAIRMAN
REPRESENTATIVES OF M-B.
FINANCE COMMITTEE
EXECUTIVE COMMITTEE
CHAIRMAN
BOARD OF REVIEW
VICE PRESIDENT AND SECRETARY AND STAFF
COMPANY MEMBER COMMITTEE
CONFERENCE OF STAFF EXECS OF M-B.
BUILDING CODE CORRELATING COMMITTEE
ELECTRICAL STANDARDS COMMITTEE
HIGHWAY TRAFFIC STANDARDS COMMITTEE
MECHANICAL STANDARDS COMMITTEE
MINING STANDARDIZATION CORRELATING COMMITTEE
SAFETY CODE CORRELATING COMMITTEE
ADVISORY COMMITTEE ON ULTIMATE CONSUMER GOODS
BOARD OF EXAMINATION MISC PROJECTS
COMMITTEE ON PROGRAM OF WORK
TECHNICAL COMMITTEES, CONFERENCES
UNITED STATES NATIONAL COMMITTEE OF THE IEC
PROPOSED CHEMICAL CORRELATING COMMITTEE
FUTURE CORRELATING COMMITTEES

Work on standards is handled by committees or conferences on which all groups concerned are represented. Most of the committees work under the leadership (sponsorship) of one or more of the organizations chiefly concerned. The American Standards Association is a member of the International Organization for Standardization (ISO).

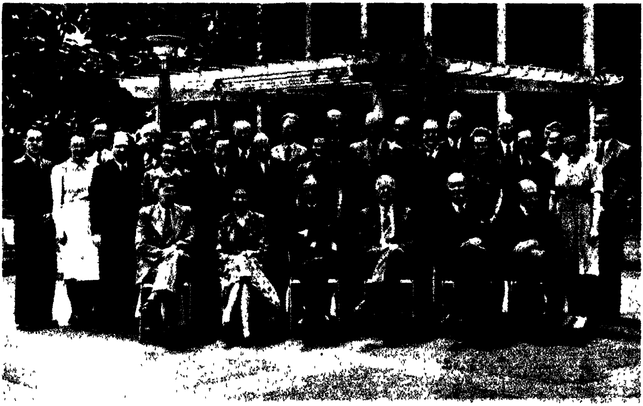
Some of the benefits experienced by these manufacturing companies from standardization are listed in this report as.

(a) Simplification of manufacture
(b) Conservation of materials and labor
(c) Ease of marketing and distribution
(d) Efficient organization operation.

In general we might summarize the status of standardization in the United States as follows, although the extent of standardization activities and the great number of organizations doing important work on standards makes it impossible to do more than touch the high spots

IN THE MECHANICAL FIELD

In the general field of mechanical engineering a number of outstanding organizations share the responsibility for the development of standards and their work is coordinated through the nationally representative committees organized under the procedure of the American Standards Association In a few instances, such as the Boiler Code of the American Society of Mechanical Engineers and the standards for special component parts which apply specifically to automotive and aircraft manufacture, the organizations representing these spe-



Members, guests and staff of the ISO, representing standardizing bodies of nine countries, met at Kongress House in Zurich, Switzerland, June 17-20, 1947. Front row, seated, from left to right: F. Streiff, Switzerland, treasurer of ISO; Miss G. Harrison, United Kingdom; G. L. Gerard, Belgium, vice-president of ISO; Howard Coonley, U.S.A., president of ISO; E. Uytborck, Belgium, president of IEC; C. le Maistre, provisional secretary general of ISO, general secretary of IEC.

Second row: W. Kuert, Switzerland; Mlle Specker, central office; R. Tavernier, France; Miss J. Marshall, central office; M. Hway, China; J. G. Mallock, Canadian representative on IEC; Mme M. Sauset, central office; D. Golinet, USSR; E. Lhoste, France; Miss W. Harle, interpreter; L. Ruppert, assistant provisional secretary general; Mme Schapper, central office.

Rear row: K. Heiberg, Norway; L. Bedin, ICAO; Percy Good, United Kingdom; P. Salmon, France; F. Furaker, Australia; M. Parlenow, USSR; G. Antonievitch, interpreter for USSR representatives; G. P. Paine, U.S.A.; Cyril Ainsworth, U.S.A.; Mlle Nicolas, official recorder; H. Abegg, Switzerland.

cial groups carry out the standardization as industry standards.

Standardization of Screw Threads

One of the most important projects in the mechanical industry is the standardization of screw threads which is being handled by a committee under the procedures of the American Standards Association and jointly sponsored by the American Society of Mechanical Engineers and the Society of Automotive Engineers

The wide representation of American industry on the Sectional Committee for Standardization and Unification of Screw Threads assures that the national standards agreed upon become the general practice in industry, as well as in government

During the war a systematic effort was started to unify the American and British standard systems of screw threads so as to establish interchangeability of screw threads between the United States, Great Britain, and Canada (26). Conferences between delegates of the three countries were held in New York, Ottawa, and London The work is still in the course of development through the national standards bodies in the three countries.

Since the war, some of the American Standards on screw threads have been brought up-to-date A recent revision of the American Standard Slotted and Recessed Head Screws, Machine, Cap, Wood, Tapping and Slotted Headless Types provides a standard greatly expanded over the pre-war edition. This is also true of the new edition of the Socket Head Cap Screws and Socket Set Screws.

The various departments of the Federal Government that are interested in screw threads have representation on the ASA Committee and also on the Interdepartmental Screw Thread Committee of the War, Navy, and Commerce Departments of the U. S Government. As a result, these American standards have become the basis of the work in the government as well as in industry (27).

Standards on Limits and Fits

Other post-war standards completed recently cover limits and fits for cylindrical parts, surface roughness, and machine tools. The standard on limits and fits, a revision of an American Standard approved in 1925, is only the first part of the proposed standardization (28). It includes a list of preferred basic sizes which is expected to help keep to a minimum the varieties of tools and gages for finishing and inspecting those parts which are to be assembled with specified cylindrical fits. One large company has reported that its drawings at one time showed 800 basic hole sizes up to 1½ inch. This new American Standard covers this range with only 30 sizes.

Studies are now being made to determine the importance of the length of engagement, bearing load, speed, lubrication, and surface finish to cylindrical fits and the results will form the basis for Part II of the standard.

The surface roughness standard is the first attempt to codify American practice on the measurement and specification of the roughness of a surface. This has been a subject of controversy for many years. This first statement (Part 1) is hailed as a contribution which will form the basis for future comprehensive and authoritative literature on the subject. It provides four different methods of evaluating the quality of surfaces and provides a symbol for use in identifying the roughness of the surface The standard means of specifying surface roughness, waviness, and lay (the visible pattern of a surface) is the standard's most important contribution

Standards for Machine Tools

The National Machine Tool Builders' Association, the Metal Cutting Tool Institute, the American Society of Mechanical Engineers and the Society of Automotive Engineers are the organizations which are responsible for the national standardization program on cutting tools and machine tool elements The program is a broad one and has been reactivated since the war to provide up-to-date editions of such basic standards as those for machine pins and involute splines.

The machine pin standards provide nominal dimensions and tolerances of different types of pins: hardened and ground dowel pins, straight pins, commercial and precision type taper pins, clevis pins, and cotter pins.

The involute spline standard has a wide application in industry (29, 30) and has been adopted by such companies as the Chrysler Motor Company, General Motors, Ford Motor Company, the Illinois Tool Works, and the Navy Bureau of Ordnance. It is important in simplification of tool design and standardization of hobs and tools The first edition approved in 1939 was not flexible enough to meet all requirements, but the new edition covers a wide range of commercial shaft sizes from the largest industrial drives to the finest splines for aircraft and instruments

Recognizing the importance of standards for machine tools, the American Society of Tool Engineers has started a standardization program in cooperation with the American Standards Association during the past year (31)

Automotive Standards

In the automotive field the Society of Automotive Engineers takes the leadership. Its most recent book of standards (32) includes SAE standards for auto parts and equipment ranging from headlamp units, spark plugs, and speedometers to specifications and tests for metals, fuel and oil hoses, and engine tests for evaluating oil. Many of these, such as the American Standards for inch-millimeter conversions, for screw threads, rivets, machine tapers, twist drills, and reamers, have been developed in cooperation with other organizations and approved by the American Standards Association as American Standards .The SAE also works in the aeronautical field and has already completed a large number of aeronautical materials specifications as well as dimensional and performance standards and recommended practices for aeronautical parts and equipment.

Aeronautical Standards

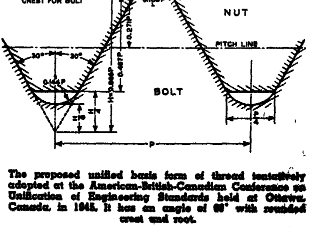
Another important national organization working on aeronautical standards is the National Aircraft Standards Committee, which serves as a coordinating organization for the standards which apply to the aeronautic problems of the aircraft industry.

How valuable the national standardization work is in this field is evident in figures given in an article by one of the outstanding standardization engineers (33). He reports that surveys showed savings ranging from 79 cents to $1.29 when National Aircraft Standard internal wrenching bolts were used instead of company standards. In addition to the dollar and cent savings, the NAS standards had been prepared with the idea of saving weight, which is an important consideration in aircraft. This report showed that one company had saved $279,960, an average of $399.94 per plane, through the standardization of wrenching bolts alone.

The Armed Forces have a high stake in the standardization work in the mechanical field because of the urgent need of interchangeability in wartime. Their proposed system of identification of antifriction bearings which would make it possible for any bearing of the same size and type to be identified regardless of the make was urged for adoption as an American Standard by the U. S. Navy. The Antifriction Bearing Manufacturers Association already had a similar system under way and consideration is now being given to reaching agreement on a single identification system which can be adopted both by industry and by the Armed Forces (34)

DRAWINGS AND DRAFTING PRACTICE

Another project which has received considerable attention during the past year is the one on standards for drawings and drafting practice (35). This was an urgent problem during the war because the practices of the Army and Navy and different branches of industry varied. In many cases, it has been reported, valuable hours were lost in copying engineering drawings provided by the services and translating them into the style which could be easily understood by the producing organizations In many cases this same procedure had to be carried out by the contractor and subcontractor as well.



The proposed unified basis form of thread tentatively adopted at the American-British-Canadian Conference on Unification of Engineering Standards held at Ottawa, Canada, in 1945. It has an angle of 60° with rounded crest and root.

Since the war, both industry and government have been working to agree on uniform drawing standards. So far, an American Standard providing 2,000 abbreviations for use on drawings has been completed (36) and a Joint Army-Navy Standard which agrees in most details with the American Standard has also been adopted.

A series of American Standard graphical symbols for use on drawings has been expanded by the adoption this year of graphical symbols for electric apparatus. A suggestion has been made by a standards engineer in one of the larger automotive companies that the various standards for drafting practice (the American Standard Drawings and Drafting Room Practice, Abbreviations, and Graphical Symbols; the SAE drafting standards and the JAN manual of drafting practice) should be combined in a single dictionary for drawings.

This is considered so important that the ASA Company Member Committee has a sub-committee studying how the drawing practice standards can be made more effective

Closely allied to the drawing standards are the national standards for letter symbols for use in engineering and scientific literature. These are now being brought up-to-date and coordinated to include many of the new terms developed during the past ten years. A sub-committee has just been formed including in its membership some of the outstanding scientists in the country to develop national standards for letter symbols for the terminology used in connection with supersonic projectiles. These letter symbol standards are more than national standards. Word has been received from Great Britain that the recently completed American Standard for Letter Symbols for Chemical Engineering, the basic work on which was done by the American Institute of Chemical Engineers, has been adopted for use in that country as well.

MATERIAL SPECIFICATIONS

The standard specifications and the methods of test which control the performance and quality of the materials that go into the equipment used by industry and the products it makes are developed by committees of the American Society for Testing Materials. In addition, a large part of the Society's activities are devoted to research work through which it is determined what method of test will accurately measure the property to be determined and give reproducible results (37, 38, 39). This Society's work covers the entire range of materials including ferrous and nonferrous metals; cementitious, ceramic, concrete, and masonry materials; paint and petroleum; electrical insulating materials; soaps and other detergents; rubber products; and textiles, among others. It has expanded tremendously during the war and is continuing to do so because of the development of new materials and the application of already known materials to new uses. New committees on engine antifreezes, structural sandwich constructions, magnesium oxychloride cement materials are a few of those organized recently. Not only has the Society grown in its work for industry, but it has also taken on more responsibility for development of standards and methods of tests for materials for use by the ultimate consumer

Mention has already been made of the activity of the Society of Automotive Engineers in the development of Aeronautical Materials Specifications.

ELECTRICAL INDUSTRY

Standardization in the electrical field is more highly developed than in almost any other. This is due to the fact that standardization of the methods of rating and testing electrical apparatus and machinery is essential to national and international trade (40) The International Electrotechnical Commission has a history of 40 years and electrical standardization by the American Institute of Electrical Engineers is 20 years older

The American Institute of Electrical Engineers initiated electrical standardization in the United States in 1886, and has continued to carry the responsibility for standardization work on problems of general scientific interest in the electrical field and on certain standards of basic importance to the program (41) Its present work is closely integrated with that of the American Standards Association

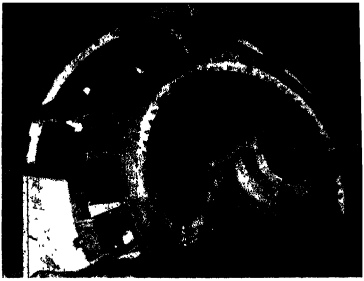
The National Electrical Manufacturers Association represents substantially all manufacturers and is concerned with the more practical aspects of electrical machinery, apparatus, and devices. During the past year NEMA has announced the completion of two series of motor standards which provide a uniform basis for rating the performance and for identifying the individual motors on a performance basis. These standards are for the widely used fractional horsepower motors which operate household equipment as well as small industrial appliances.

The important standards which have a national application, such as those on transformers, circuit breakers, rotating electrical machinery are processed through the nationally representative committees of the American Standards Association A new and up-to-date edition of the American Standard for Transformers, Regulators, and Reactors is now nearly completed.

The National Electrical Manufacturers Association is also interested in standards being developed by nationally representative committees of the American Standards Association for domestic electrical equipment, such as electric stoves, irons, and toasters. These standards are intended to provide a criterion of service to help the user to select the equipment best suited to her needs.

A meeting in Switzerland in October, 1947, considered international agreements on methods of preventing electrical interference with radio. This was considered of special importance by American industry because many of the countries which will buy radio and electrical equipment from the United States in the next few years have regulations providing that such equipment must follow certain rules for the prevention of radio interference.

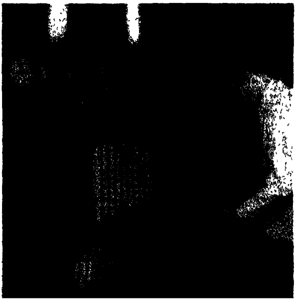
The present rapid growth of the radio industry has brought a demand for faster development of standards to meet its expanding needs. The Institute of Radio Engineers and the Radio Manufacturers Association are both active in the national program. At the request of the Institute of Radio Engineers, work is going forward

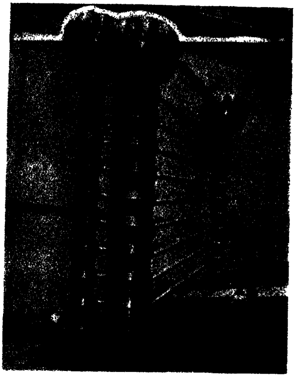


A rotary converter capable of supplying 5,400 kw. The American Standard for rotating electrical machinery covers service conditions, tests, ratings, temperature limitations, efficiency, voltage and speed regulation, terminals markings and nameplates.

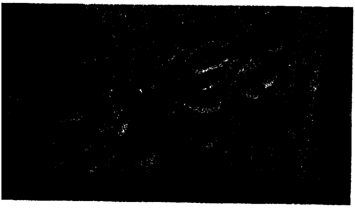
Experiments to determine the explosive characteristics of hazardous dusts before standards are agreed upon.

The content and quality of chemicals used in photographic processing are now included in standardization for photographic equipment and materials. More predictable results are assured.





Research at the National Bureau of Standards was basis of recommendations for the protection of industrial workers using X-ray equipment.



To minimize injury to motorists from broken glass, tests were used to develop safety glass specifications.

The wear on single-point cutting tools for use on such machines as lathes, turret lathes, boring mills, planers and shapers may now be determined according to standard on tool life tests.

to include broader representation from the radio and electronic interests in the Electrical Standards Committee of the American Standards Association. This is expected to provide the means for rapid development of the standards needed by the radio industry and at the same time maintain uniformity between similar components used by both the radio and electrical industries.

ACOUSTICS

Scientific work on standards in acoustics is being done through the procedures of the American Standards Association under the leadership of the Acoustical Society of America Work is now being done on a standard for measuring the performance characteristics of loud speakers and on basic reference levels for sound measurements Drafts have already been prepared on audiometers needed for diagnostic purposes, experience with which is expected to be helpful in the preparation of performance requirements for hearing aids.

PHOTOGRAPHY

Standardization has an obvious and special significance in the photographic field The widespread use of all makes of film and the growing popularity of photography as a hobby have made it increasingly important that the photographer can procure exactly the type and size of film, and the kind and type of photographic and processing equipment and materials he needs (42) Recognizing this demand on the part of their customers, the film, camera, and equipment makers have joined with the other groups concerned in a comprehensive standardization program covering dimensions, performance requirements, specifications, and methods of test for film and photographic equipment, for chemicals used in processing, and definitions of the terms used This includes a definition of what constitutes the speed of film and the calibration of exposure meters. Some of this photographic work has been adopted by similar groups in the British Commonwealth of Nations.

The Society of Motion Picture Engineers and the Motion Picture Research Council are taking the responsibility for similar standardization programs on motion picture film and equipment (43).

The American Standards Association holds the secretariat for still and motion picture projects in the International Organization for Standardization and is taking steps at the present time to actuate this phase of the work.

THE BUILDING FIELD

The outmoded and non-uniform building codes which in many cases are blamed for contributing to the high cost of building in the United States today are most obviously in need of standardization. Nationally representative committees are working under the Building Code Correlating Committee of the American Standards Association to prepare standards based on performance requirements rather than on specifications for materials and equipment for use in uniform building codes (44). These committees work closely with the National Bureau of Standards which is doing research on fire resistance, floor loads, combustible loads on certain types of building, and on requirements for chimneys and heating appliances. The National Housing Agency is co-operating. As a result of this research, requirements can provide, for example, that the material used in a floor or wall must be able to withstand a certain amount of heat or flame for a certain period of exposure rather than that a certain material of a specified weight or size must be used.

Committee E-6 on Methods of Testing Building Construction of the American Society for Testing Materials is now starting to develop methods of test to determine the adequacy of the new materials and types of construction The results of its work will be available for use in building code standards.

Considerable work has been done on the development of uniform building codes to be recommended for adoption by state and municipal authorities The Pacific Coast Building Officials Conference has long had a code, which has been adopted by more than 400 municipalities, mostly in the west. It is kept up-to-date and is revised frequently

The National Board of Fire Underwriters, the national trade association of the stock fire insurance companies, developed a uniform building code for use by municipalities many years ago It has been revised frequently in order to keep it in tune with new developments.

The Building Officials Conference of America is now circulating a proposed model building code for comment

The uniform adoption of a code based on performance requirements rather than on specifications would go a long way toward speeding building through the use of new and more efficient materials and more modern techniques. That the adoption of up-to-date building codes is urgent has been demonstrated in a tragic manner during the past few years (45) Experts point out that loss of life in fires such as the Winecoff Hotel fire in Atlanta, Georgia, and the Boston nightclub fire of 1942 could have been largely prevented, if the requirements of the American Standard Building Exits Code developed under the leadership of the National Fire Protection Association had been in effect. All of the buildings in which the major loss of life has occurred have fallen far short of the present standards of this code. The exit requirements for hotels and apartment houses are even now under revision. The new edition will probably be completed early in 1948

One of the recent developments which is contributing toward lower-cost building is the project on modular coordination (46). Through this program, building equipment and materials are designed on the basis of a four-inch unit to fit together at the building site. This plan has been applied by the Producers' Council and the National Retail Lumber Dealers Association in the design of an "Industry Engineered House" (47), which is pre-planned so that the exact size and number of pieces of material and equipment needed can be ordered, thus preventing cutting and piecing at the building site. It is expected that this plan will be of special help to small local builders who do not have facilities for the large scale operations necessary to put into effect the most economical methods. Producers of such building materials and equipment as bricks, concrete building units, and certain types of modular steel windows have announced that their products are available in modular sizes The plan of modular coordination is being widely used for the construction of veterans hospitals, by city building departments, and by institutions as well as by private construction companies. The Modular Service Association of Boston is carrying out the detailed work needed to put the standards developed by ASA Sectional Committee A62 into effect.

STANDARDS FOR CONSUMER GOODS

Ever since the organization of the American Engineering Standards Committee in 1918, industrial consumers have been working with producers to reach agreements on standards of quality, performance, and dimensions for the material and equipment they buy. Within the past few years, producers and distributors have begun to be aware of a need for similar work on household equipment and supplies (48). This has been especially true since the development of synthetic materials, highly complicated mechanical and electrical devices, and packaged foods and similar materials

Such organizations as the National Retail Dry Goods Association and the National Association of Hosiery Manufacturers have asked the American Standards Association to organize nationally representative committees to develop standards for women's nylon hosiery, women's dress sizes, and designations for the identification of rayon Under the leadership of the National Electrical Manufacturers Association, standards for the safe operation and satisfactory performance of electric flatirons, electric ranges, and electric water heaters used in homes are nearing completion. The standards will include recipes for baking biscuits to determine the efficiency of ovens as well as requirements for electric wiring, insulation, and strength of the mechanical parts. In developing standards for women's industrial clothing, the sizes proposed will be based in part on data obtained by the U S Army when it measured the women who served with the Armed Forces during the war. The American Association of Textile Chemists and Colorists is doing research that is expected to form the basis for recommendations as to the number of washings colored textiles should stand without appreciable change in color.

Calling attention to the importance of the new demand for standards for consumer goods, the American Society for Testing Materials recently established an over-all Administrative Committee on Ultimate Consumer Goods, advisory to the technical committees that are working on projects relating to the consumer goods field

Some groups of manufacturers have found that the use of standards offers a good selling point to their customers when their products are certified as being in accordance with the standard. The American Gas Association has had such a program for many years. Its AGA Seal of Approval indicates to the public that the gas stove, or water heater, or other appliance on which the Seal appears, works satisfactorily and safely. Recently a group of lamp manufacturers launched a sales program based on standard tests for their lamps (49). The

Electrical Testing Laboratories carries out the tests on the lamps and certifies to their compliance with the standards agreed on. Seals of Approval are attached to these lamps and are featured in the advertising campaigns.

A new American Standard outlining the procedures to be followed for assurance that certification is valid was approved by the American Standards Association in 1947. The National Electrical Manufacturers Association considers this subject so important that it has asked for comments on a statement of policy on certification labeling which had been endorsed by its Board of Directors (50).

STANDARDS FOR SAFETY

It is impossible to estimate the amount of savings to industry and the general public made possible through the application of safety standards to potentially dangerous working conditions (51). Some 150 American Standard safety codes now in effect offer recommended safe practices for such diverse problems as fire tests for building materials, safety shoes for industrial workers, the use, care, and protection of abrasive wheels, prevention of dust explosions, and safety glass for automobiles (52, 53, 54). Such standards are part of the national drive to reduce the accident rate sponsored by such organizations as the National Safety Council, the National Fire Protection Association, the American Society of Safety Engineers, state labor and safety officials, and other groups interested in the safety movement.

American Standard safety codes are generally recognized as authoritative because they are developed by nationally representative committees in which the viewpoints of all groups concerned — industry, insurance, safety, labor, and government—are considered. They are widely used by state regulatory bodies (55, 56). Without uniform regulations, industry is faced with the necessity of building machines to meet different requirements in each state. In the early history of state safety regulations, Pennsylvania's safety requirements made a machine unsafe in Wisconsin.

This problem was one of the important considerations in a request from the American Society of Bakery Engineers recently for an American Standard Safety Code for the Bakery Industry (57) This first national safety standard for the protection of bakery workers was completed within the past few months. The same consideration is also important in the work now being done to revise the American Standard Safety Code for Mechanical Refrigeration. Increasing use of air conditioning, freezing units, and frozen foods has brought a wave of conflicting regulations for safe installation of refrigeration equipment from the state regulatory bodies. Because the code is out of date, the states have no guide for the development of uniform regulations for the new installations. Under the sponsorship of the American Society of Refrigerating Engineers, the work on a revised edition is now being speeded as a protection to manufacturers, distributors, workers, and the general public.

Industry benefits directly from the use of American Standard safety codes through the fact that insurance companies use these standards as the basis of recommendations to the insured for the removal of accident hazards The premiums charged reflect the degree to which the insured, among other safety activities, is meeting the requirements of the safety standards.

GOVERNMENT STANDARDS

Cooperation by government and industry in standards developed by government agencies is greater since the war than it had ever been before. A Policy Committee on Standards, headed by Charles E Wilson, President of the General Electric Company, was appointed soon after the end of the war by the U. S. Department of Commerce to make recommendations on methods of carrying out the future program (20, 21). This committee has recommended that the main activity in the development of industrial standards and standards for consumer goods should be done by industry through the American Standards Association. Secretary of Commerce Harriman has asked this committee to continue its work. It includes in addition to Mr. Wilson: Dr. Frederick M. Feiker, Dean of Engineering, George Washington University; Clarence Francis, Chairman of the Board, General Foods Company; Ephraim Freedman, R. H. Macy & Company, Inc; Dr. Frank B. Jewett, President, National Academy of Science, Arthur D. Whiteside, President, Dun & Bradstreet, Inc.; R. E Zimmerman, Vice-President, U. S. Steel Corporation.

Another committee of executives from industry and important trade associations and technical organizations is acting as an advisory committee to the Federal Specifications Board, bringing industry's viewpoint into the development of standard specifications for the supplies used by all of the Government's executive agencies. The extent of this task is indicated by the fact that, as of May 31, 1947, there were 9700 specifications for government purchasing, including Federal Specifications, Army, Navy, and Joint Army-Navy specifications (58). Federal Specifications are issued by the Bureau of Federal Supply of the Treasury Department and developed by technical committees under the supervision of the Federal Specifications Board. The Director of the National Bureau of Standards is chairman of the Board, which is made up of representatives of some 11 Federal agencies. The Standards Branch of the Bureau of Federal Supply furnishes technologists who work with 77 specialized technical committees in developing the specifications. These committees have a combined membership of approximately 1300 technical experts drawn from throughout the Federal Government. When the equipment or supplies purchased by a Federal agency must meet special requirements, as in the case of the Army and Navy, that agency sets up its own standard specifications. A serious effort is being made by the Armed Services to coordinate their requirements in the interest of interchangeability of parts and equipment through the Joint Army-Navy Specifications.

The National Bureau of Standards is the principal agency of the Government for fundamental research in physics, chemistry, and engineering, and has the custody of the fundamental standards of weights and measures which are used in calibrating all the working standards in research laboratories and industry (59) A recent announcement by the Bureau calls attention to a "new and better standard of length" than the platinum-iridium meter bar which since 1889 has been the world's standard The new standard is the wavelength of green radiation of mercury 198, an isotope transmuted from gold by neutron bombardment, which the Bureau explains gives a more accurate measurement than the meter bar (60)

As the service to industry, the Bureau issues Commercial Standards for manufactured products and Simplified Practice Recommendations (61) to eliminate avoidable waste by listing those sizes, types, dimensions, and varieties of manufactured products that satisfy major demand This work is done at the request of the industrial group concerned

It also does a great deal of work on safety codes, plumbing codes, building codes, and specifications for construction, building materials, and other commodities The Bureau is a member of many of the committees of the American Standards Association and acts as administrative leader for 16 of them Announcing that work is being started on a revision of the American Standard Safety Code for Elevators, which the Bureau sponsors jointly with the American Institute of Architects, the Bureau declared recently that these code requirements and the testing and certifying of elevator safety devices have resulted in a steady decrease in the number of elevator accidents throughout the United States during the past 20 years, despite the fact that the number of elevators in use has increased materially This offers an excellent example of the way in which the Bureau cooperates with industry In addition to serving as a sponsor for this American Standard project, the Bureau has carried on research which has provided data for use in preparing the standard. Test procedures to detect weaknesses and cause of failure in elevator hoistway door interlocks and in undercar hydraulic buffers were approved by the sectional committee on the basis of several years of research done at the Bureau Similar cooperative work is now going on in connection with the development of a safety code for the protection of industrial workers using X-Ray equipment

Standards activities of several of the Government agencies have a special and direct effect on the general public These include the Civil Aeronautics Board which promulgates safety standards in the form of civil air regulations, the Food and Drug Administration which maintains supervision over products sold in interstate commerce which are subject to the Federal food, drug, and cosmetic laws, and the Federal Trade Commission which is charged with preventing unfair methods of competition and unfair or deceptive acts or practices in commerce

The Civil Aeronautics Board, which promulgates safety standards, and the Administrator of Civil Aeronautics, which enforces safety standards, rules, and regulations, together make up the Civil Aeronautics Authority The Civil Aeronautics Board also provides information and coordinates its activities with those of the International Civil Aeronautics Organization in the development of all international safety and operational standards

The Federal Trade Commission, in a large measure, bases its findings on standard definitions, specifications, and methods of test In many cases, if standards are not available it is necessary for the Commission to formulate them before it is possible to determine whether a trade practice is unfair or deceptive

Standards for food and drugs are prepared by the Food and Drug Administration of the Federal Security Agency as a basis for its inspection of factories for sanitary conditions and the packaging and labeling of products destined for interstate shipment The Food and Drug Administration also makes intensive studies of trade practices and consumer understanding in preparing definitions and standards for food shipped in interstate commerce

The Division of Labor Standards of the U. S Department of Labor is responsible for helping to develop and promote standards of safety and health, and for providing technical advice and service on safety and health to state labor departments, trade unions, and trade associations Upon request, they assist in the preparation of state industrial safety codes.

CONCLUSION

In summarizing the place of standardization in modern industry, an article published recently by the Royal Bank of Canada (62), succinctly states the problem:

"In times of peace, standardization may mean that the manufacturer will have less capital tied up, greater volume of production, with lower costs; more efficient inspection and consequently better customer satisfaction, reduced accounting, record, and office cost; and a more even flow of production, providing improved service to purchasers in quality and in promptitude of delivery It is obvious that a standard way of assembling a watch or an automobile will give better returns in terms of quantity and quality than a haphazard way.

Illustrations for this chapter were obtained through the courtesy of American Standards Association, FIA Fire Safety Laboratory, National Bureau of Standards, Westinghouse Electric Corp, and the International Organization for Standardization

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CHAPTER XXVII

TEXTILE INDUSTRY

by JULIAN S. JACOBS

THE ECONOMIC FRONT

Rarely, if ever, has a major industry experienced an upheaval of the magnitude of that which has occurred in recent years within the textile industry of the United States. The shock of this upheaval which has disturbed the economic front of textiles has not been without its effect upon the technological front as well.

Integration

Although the main intent of this paper is to recount the technological progress in the textile industry, the reorganization which has been taking place within it is fraught with such far-reaching significance that it claims first place in this discussion.

Consolidation of ownership and control of manufacture and distribution has progressed with such rapidity that, at the present time, an estimated (1) 75 per cent of the cotton industry is fully or partially integrated, compared with 25 per cent before the war. Although integration had its beginnings principally among the cotton interests, at least one organization, known chiefly for its woolen and worsted products, has expanded to include cotton and rayon fabric manufacturing units and now has some 30 mills in the combine.

Integration has been both vertical and horizontal. In the past, many (perhaps a majority) of the cotton mills carried their manufacturing processes from the cotton bale only to an intermediate product called gray goods (unfinished cloth as it comes off the loom). Gray goods were marketed, for the most part, to converters through commission houses and selling agents. The converters sent them, on account, to be finished, bleached, dyed, printed, etc.) to mills which specialized in the finishing processes. The converters then marketed the finished goods.

For familiar reasons induced by wartime conditions, among which was the necessity either of securing needed raw material or of goods for distribution, there have been formed vertically integrated organizations embracing two or more steps in the chain of operations. Illustrative of the extreme type of fully integrated company is Textron (2), whose organization encompasses every step from cotton bale to ultimate consumer product.

Horizontal integration—that is, the merging of units on the same level into one organization—also has not been neglected.

Conjecture has been rife, and heated arguments pro and con have been frequent, concerning the permanence of these mushroom growths and their long-range effect on the industry. Certain published reports (3, 4) have weighed the advantages and disadvantages of different types of integration. A recent magazine article (1) furnishes a clear picture of the development of integration, citing numerous examples. It also discusses factors which have affected the welfare of the industry since its foundation. Charts, covering the period since 1920, illustrate the trends of raw-cotton prices, gray-goods prices, wage rates, mill margins, profits, and production. A report by Dall (5) deals with the epidemic of mergers and lists the textile-mill mergers and acquisitions for the period January, 1944, to June, 1946, inclusive.

Some have held that the trend toward consolidation has been impermanent, since huge, losely knit organizations are unwieldy and, like houses built of cards, will not stand the winds of competition. They point out that already units are being dropped or closed.

Others maintain that such organization means the salvation of an industry which has been comprised of a multitude of small units with comparatively few large or strong ones, an industry which grew like Topsy, and which has lacked cooperation and efficient management; that much of its machinery and many of its manufacturing methods were obsolete; that it lacked the science and technology necessary to survival in modern times. They maintain, for example, that combination insures the capital required for extensive research, and for the application by industry of the results of research. The latter will include replacing much present-day machinery with machines of radically different design and eliminating many intermeidate steps in manufacture in favor of continuous processes.

The Cotton Belt

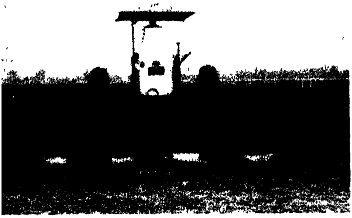
Early in the war, wide publicity was given to a catch phrase, "the Battle of the Fibers," referring to the ascendency of rayon and synthetic fibers. "King Cotton is Doomed," so ran the headlines. Dire predictions were made concerning the future of the cotton industry, upon which the major economy of a large part of the South depends.

There was, indeed, sufficient basis of fact to justify alarm. Military specifications required the substitution of rayon and nylon for cotton in tire cords; improvements in rayon fibers and in rayon fiber and fabric treatment indicated that rayon would capture certain apparel markets previously held by cotton; and the cost of raw cotton had risen so much that rayon could compete with it on a price basis.

The result, however, has awakened the cotton interests to the necessity of abandoning dependence on an artificially supported price structure and of giving technology free rein to do five important things: (a) introduce greater mechanization and improved agricultural practices and soil conservation to produce cotton at a price which would yield a fair return to the grower and at the same time insure a market of from 13 to 15 million bales annually; (b) produce an improved quality of lint which would reduce processing costs at the mill; (c) develop ginning machines to preserve fiber quality and improve the grade of both machine- and hand-picked cotton; (d) expand research in the field of cotton processing and marketing in the interest of increased efficiency, and (e) develop improved manufacturing methods and new fiber and fabric treatments.

In a report by Dr Frank J Welch, Dean of the School of Agriculture, Mississippi State College, to the National Cotton Council at a meeting held in Stoneville, Mississippi, August, 1947, it was brought out that 14-cent cotton would be needed to maintain the market mentioned above It was estimated that a stabilized market of between 14 cents and 20 cents might be expected.

Worthy of study is the report of the "Hearings Before the Special Sub-committee on Cotton" (The Pace Committee) (6). This 877-page document covers a fact-finding program which was divided into 9 projects, among which were "Adjustments Toward Efficient Agriculture in the South"; "Cotton Goods Production and Distribution Techniques, Cost, and Margins"; "The Competitive Position of Cotton and Other Materials"; and "Production Studies of Synthetic Fibers and Paper."



Mechanical cultivation of cotton also includes killing weeds with flame cultivator.

Technological developments in the raising of cotton will be treated in the section on fibers in this paper, but one economic bugaboo seems to be disappearing Even now, before mechanization can become general, one finds empty shacks on every hand in the cotton-growing areas owing to the migration of workers to more lucrative occupations Cotton still unpicked at planting time in 1945 was mute evidence of the loss of labor (7) The problems of what to do with workers displaced by machines evidently will solve itself.

THE TECHNOLOGICAL FRONT

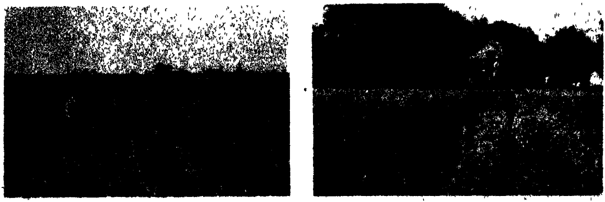
I. FIBERS

The Natural Fibers

In the field of natural fibers, the outstanding developments of recent years have been in cotton production, with progress also evinced in the cultivation and mechanical decortication of ramie. Fiber treatments and chemical modification will be discussed in later sections of this paper.

Mechanization of Cotton Production. Although a patent was issued as far back as 1850 (8) on a mechanical cotton harvester, and the first patent to Campbell (whose patents were later acquired by the International Harvester Company) in 1895, it was not until the early 1940s that improvements in spindle-type pickers led to large-scale experiments with mechanical picking. Gerdes reported (9) in 1945 that more than 100 spindle-type pickers were in use that season. A history of the development of cotton harvesters (8) describes the various types and lists over 650 U. S. patents granted through 1931. Cotton strippers are being widely used in West Texas and Oklahoma for harvesting short-staple cotton after frost late in the season (10).

Along with a practical harvester has been the development of mechanical choppers and also flame weed killers (11, 12). Remarkable savings in labor have been reported (13, 14), so that complete mechanization is, at least in certain areas, nearing the practical stage (15). However, many related problems still must be solved



Cotton picking has been revolutionized from hand picking (left) to modern machine method (right).

before a general program of mechanization can become a reality The U S Department of Agriculture states (16) that "Although widely publicized, the use of mechanical pickers in harvesting cotton has been negligible from an over-all crop standpoint"

Notable improvements in ginning have recently been made (17). Processes for cleaning lint in the gin, supplementary to the ginning operations, have been developed by the U S Department of Agriculture Ginning Laboratories and the gin manufacturers, thus making mechanical harvesting more profitable Better methods of packaging are under consideration (18, 19) Improved strains and reduction of the number of varieties of cotton in principal production to 6 major and 3 minor varieties have been reported (20) Berkley (21) has reviewed in detail recent cotton research including some unpublished data on fiber variations and relationships

Ramie The history of attempts to promote the use of ramie in the United States since it was first introduced about 1855 has been one of repeated failures in spite of its many superior characteristics as a textile fiber Only within recent years has serious attention been given to its culture and to mechanical processes for decortication and degumming, which, in the Orient, have been done solely by hand Only in the past two years has the work undertaken by large interests approached the development stage. In December, 1945, Dall (22) discussed the status of ramie, its history, physical properties, problems of preparation and uses, and gave a roster of firms which have handled, processed, or promoted it Robinson (23, 24) gives the total production of fiber in 1946 as 130 tons An unofficial estimate of the 1947 production is 1,000 tons.* The years 1945 to 1947, inclusive, have seen the entry of a number of firms into the field A recent report (25) describes these developments and discusses progress to date, problems to be met, and the outlook for the ramie industry

Flax A new variety of flax called "Cascado" is under experimental development. It appears to have promise because of its resistance to rust.

Hemp Work is in progress on the chemical decortication and experimental spinning of hemp. Also a new variety is being experimentally cultivated A characteristic of this variety is its heavy yield of seed

Synthetic Fibers

Improved tensile strength and other physical and mechanical properties, improved staple, and the development of new types with special characteristics, together with the advent of crimped and tapered fibers, have added greatly to the versatility of the older, well-known types of rayon and synthetics. In addition, new fibers have appeared—some of them with built-in properties capable of being controlled by variation in the treatment they receive during manufacture in order to adapt the fiber to specific end uses. Another sign of progress is the number of new firms entering the field of manufactured fibers.

In the last year or two the synthetic fibers have been the subject of some readable and informative books and articles* A recent issue of *Textile World* (26) features a chart giving a complete list of all the synthetic yarns and fibers, both filament and staple, that have reached the stage of commercial production, as well as their physical properties, uses, methods of manufacture, the available denier sizes and staple-fiber lengths, and the addresses of the manufacturers There is an excellent review (27) of the field as it was at the beginning of 1945 which gives the properties and potential uses of the principal types then in commercial use and also of some which still are in the experimental stage. Another review (28) of fibers includes discussions of fiber and fabric treatments and finishes The Shermans in their book, "The New Fibers" (29), provide a detailed account of fibers currently in use and under development. A chapter is devoted to chemical treatment of fibers and a section of particular interest to technicians lists more than 1,600 patents.

Among the interesting new arrivals is Vinyon N (30), of the family of vinyl resin fibers, a copolymer of vinyl chloride with acrylonitrile It is attracting much attention because it appears to offer superior characteristics as a textile fiber It is an excellent illustration of the wide diversity of properties that can be built into a fiber to suit the application Five or more distinct types of Vinyon, each with different characteristics, can be manufactured from the basic resin. These range from one with relatively low tenacity but with exceptional crush- and abrasion-resistance and resilience, suitable for pile fabrics, to one with strength as high as 4 3 grams per denier and low elongation, which appears

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* The Fall, 1947, hurricane caused serious damage to the crop in the Florida area which will make the actual production far below this estimate.

* In view of the lack of agreement as to a systematic classification, or even a generic term, for manufactured fibers it is becoming common practice to apply the term synthetic to all other than the natural fibers.

promising for cordage. The latter has the highest heat resistance, its shrinkage at 284 deg F being practically negligible. All of the Vinyons (31, 32) exhibit remarkable resistance to chemical and biological degradation

The acrylonitriles (29, 33) belong to an entirely new class of fibers The industry is awaiting with interest the commercial appearance of Du Pont's Fiber A. Like Vinyon N it is a copolymer, but is reported to have acrylonitrile as the principal component, with such desirable properties as high strength, low density, and resistance to mildew and chemicals It is said to be capable of giving fabrics a silk-like hand. Few details of Fiber A are available up to this writing. However, a survey of the polymers, their preparation, and properties has appeared (34)

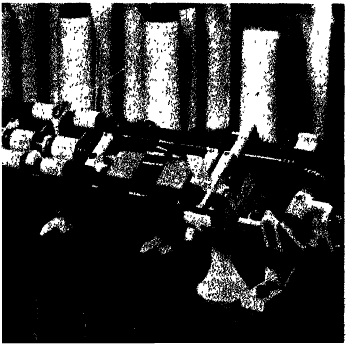
Another class of copolymers—vinylidene chloride—the development of textile uses for which was interrupted during the war, is now being manufactured as monofilaments by several firms (and multifilament yarns have been shown). These products are Saran (35) by National Plastics Products Co. and by Lus-Tras Extruded Plastics Co (a newcomer); Velon (36) by Firestone, and Viscord by the Visking Corp. Vinylidene chloride is thermoplastic and softens at 200 deg. F It has found uses in window screens, upholstery fabrics, hand bags, etc. It is a strong fiber and is unaffected by most chemicals.

Polyvinyl-chloride filaments have been made experimentally, as have multifilament yarns from polystyrene

A plastic-coated yarn based on a core of cotton, synthetics, linen, etc., has appeared on the market under the trade name of "Plexon" (37)

Several new varieties of nylon have been reported, among which is a new elastic one with properties akin to those of rubber The elastic modulus of this polyamide is said to be 20 times that of rubber fiber and the tensile strength 5 times as great. And, in 1947, nylon made its bow as a staple fiber (38)

Shaw long-draft spinning system: At right, top rolls are removed, exposing apron.



Of the protein-base fibers, recently given the generic name "Azlon," Aralac, from casein, appears to be the only one in commercial production, although the Drackett Corp was expected to launch "Soylon" (soybean protein) as a full-fledged fiber by the end of 1947 Considerable progress is being made both in the United States and England on vegetable proteins. The Regional Research Laboratories of the U. S. Department of Agriculture are working on these The Eastern Laboratory (Philadelphia) is active in the improvement of casein fiber (39, 40). Dry strength as high as 1.0 gram per denier (the dry strength of wool is about 1.3 g./den.) and wet strength of 0.7 g./den have been reported. A study is in progress there also on the relationship between the molecular structure and fiber properties of natural and synthetic protein fibers (41). The Western Laboratory (Albany, California) is developing fiber from chicken feather keratin (42). The Southern Laboratory (New Orleans) is working on a fiber named "Sarelon" (43) from peanuts, and the Northern Laboratory (Peoria, Illinois) is working with Zein, a protein from corn meal (44). A new entrant into the field of manufactured fibers is the Virginia-Carolina Chemical Corp, with another fiber from peanut protein, which has been trademarked "Vicara" (45).

In England intensive development of fiber from peanut protein has been underway; the British have named it "Ardil" Although considerable data have been published (46) concerning the experimental preparation of the fiber, its properties, and experimental fabrics made from it, very few details concerning its further development and the extent of its practical use have found their way into literature

The British have pioneered also in the development of rayon from algin products obtained from seaweed (47-49) As a result, a series of fibers with interesting characteristics have been produced. Whereas some of these are alkali-resistant, a unique feature of calcium-alginate rayon, for example, is that it is easily dissolved by ordinary scouring processes. It possesses satisfactory elastic properties for weaving and knitting and can be used as a carrier for soft and even twistless yarns. After the fabric has been made, the alginate fiber is dissolved out.

A new fiber-forming polymer, "Terylene," derived from terephthalic acid and ethylene glycol, has been announced (50) by Imperial Chemical Industries. Technical reports have appeared which deal with the chemical and physical structure of the fiber (51, 52), and recent progress in development has been reported (53, 54). This new fiber is characterized by exceptional resistance to light, heat, and moisture. It has a high elastic modulus and excellent resilience. Fine filaments below one denier are said to have been produced. At present the difficulty of dyeing tends to restrict its use.

II. ADVANCES IN MANUFACTURING PROCESSING

A New England textile manufacturer predicted in

1911. "The day will come when the raw stock will start in the mixing picker and not be touched by hand until it appears as a fabric." Had he lived, he would have seen his dream approach reality. As a matter of fact, the bonded-web fabrics today fulfill that prediction, although they are for specialty purposes and are not yet adapted to wearing apparel.

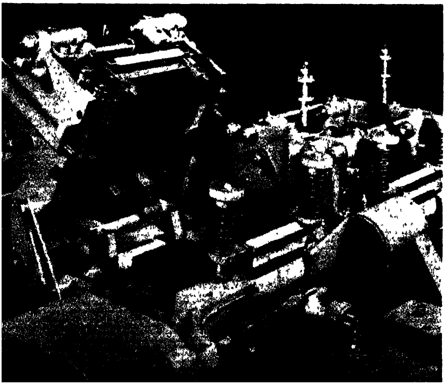
Recent years have seen the elimination of many intermediate processes—fewer drawings and doublings, for example—and the practical operation of continuous processing. In these advances the engineer has worked hand-in-hand with the chemist, for new chemical treatments have called for new mechanical equipment and, for successful operation, both have required electronic instrumentation for rigid control.

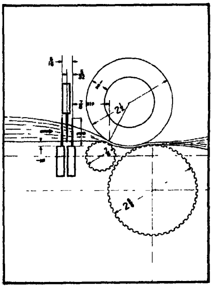
Conversion of Fiber to Fabric

Released from restrictions of war production, the textile industry has engaged in a reconversion and modernization program of great magnitude. Figures on expenditures and commitments for 1947 indicated a gain of 35 per cent over the total dollar volume for 1946, with a total expenditure for 1947 of nearly 415 million dollars (55). Advances have been made all along the line, not only in new processes and machinery of radically new design, but also in refinements and improvements to equipment on hand, with the aim of increasing production, improving the product, and permitting better control of operations. Rapid progress has been made also in devising better methods for materials handling, evidence of which may be found in the pages of textile publications, which continue to describe new installations which have resulted in notable savings. Space here will permit touching only the highlights of recent progress; the annual reviews (56, 57) of the field give additional discussions of progress and trends.

Spinning. Present-day spinning and roving frames are greatly improved over those of a few years ago. Although the long-draft roving frame was built as long ago as 1932, long-draft spinning has come into its own only in the last few years. Two of its main advantages are greater flexibility in the use of fiber lengths and the elimination of some of the conventional multiple doublings. One mill which has had a long-draft system in operation for 4 years reports remarkable saving in the card room. Now only 4 rovings are made, whereas on the old system as many as 12 were often run (58). At the same time, stronger yarns are possible provided there is close control of uniformity of sliver, roving, and yard. An automatic uniformity tester, and other devices for the same purpose, have been described by Vose and Plummer (59). Another article (60)) describes some of the principal long-draft systems currently in use.

The recently instituted "American System," employing the long-draft principle by which worsted yarns can be spun successfully on cotton frames, is attracting wide interest both in the United States and abroad. The fact that cotton mills can now make worsteds on their system at a considerable saving in production costs has brought them into competition with the old-line manufacturers of worsteds. It is claimed (61) that, with the two systems running side by side, the American showed an estimated saving of $10.00 per spindle per year on a two-shift basis as compared to the regular worsted system. In articles by McConnel and Bogdan, one type of organization designed for this system (61) and another for spinning 40s worsted count yarn from top wool in 4 operations (62) are outlined. However, certain limitations remain to be overcome. For example, there are minimum and maximum limits to the length of fiber which can be accommodated, also the top used must be much more uniform than that required for the regular systems. It is believed that it will be necessary to over-





Warner and Swasey double-head pin drafting machnism. Drafter with one head opened to reveal long faller bed. Three-roller drafting assembly.

come these limitations before the system will have wide acceptance.

The advent of staple synthetic fiber has given great impetus to fiber blends, which has led to much work on their use on cotton as well as on woolen and worsted machinery systems (63). A very promising new roving frame, and other important developments now underway, are expected to provide the versatility necessary for handling a wide range of fiber lengths According to a recent announcement (64), the new pin-drafting machine manufactured by the Warner & Swasey Co. is going into mass production This machine is said to handle wool, cotton, synthetic staple, or blends of these fibers, and to reduce the number of steps in the operations between combing and roving

Mention should be made of the methods for producing staple fiber from rayon tow, which is known as *tow-to-top conversion*. A rope-like collection of continuous filaments, called "tow," is processed to break the filaments into suitable lengths for carding and spinning Tow may also be broken or cut to make conventional top for spinning on the worsted system Two systems, the Perlok and the Campbell, developed in the United States, have been described (65). Details concerning a third, in use at Pacific Mills, have not been released A fourth system is the Greenfield, developed in England (65, 66)

Yarn is being produced directly from card sliver or from roving without spinning At Riverside and Dan River Cotton Mills this is accomplished in two steps: (a) impregnating the roving with a suitable resin, and (b) curing it under heat and tension (67). Avondale Mills now have a system capable of spinning yarn directly from card sliver (68), known as the Avon drafting system, in which the conventional roving and spinning processes are done by a single machine. The system, basically a set of long-draft slubber rolls running in tandem with a set of long-draft spinning rolls, consists of five sets of rolls, two sets of which are covered with short carrier aprons This assembly has proved successful for drafts up to 300, with drafts up to 600 having been used experimentally

The United States Rubber Company's Textile Division has, by a special process, constructed a yarn in the shape of a coiled spring. This was first made in 1947, from cotton, although the Division expects to work also with wool, synthetics, and other fibers. From this coiled-spring yarn an elastic fabric has been woven which is called *Strex* (69). The amount of elongation can be regulated from 30 to 100 per cent, depending on specific purposes, and the fabric can be made with equal stretch warpwise or fillingwise, or the stretch may vary. Strex found its first practical application in surgical bandages, but it appears to have interesting potentialities.

Weaving. A mild revolution in the field of weaving machinery appears to be a possibility. Several looms of radically different design from the conventional one have been built abroad. It is also rumored that firms in this country which previously had not manufactured textile machinery are experimenting with looms of new design One of these, the F. W. Kellogg Co., a subsidiary of the Pullman Company, is reported to be building a battery of looms for large-scale trial. Another rumor has it that a large shipbuilding company is planning to manufacture looms.

The foreign-built loom which is attracting the widest attention is the Sulzer bobbinless-shuttle loom, a Swiss product. It is said to operate at 230 picks per minute, or higher, for a triple-width fabric, whereas the speed of U S. looms is approximately the same, or lower, for single-width fabric. Descriptions of the Sulzer loom have appeared in various periodicals (70, 71). An American version is in experimental development (December, 1947) by the Warner & Swasey Company, a well-known builder of machine tools Shuttleless looms for specialty purposes have been invented in England (72-74).

Bonded webs, or non-woven fabrics, are being developed for a number of new purposes. In addition to the earlier, well-known products such as tea bags, disposable tissues, surgical gauze and the like, fabrics such as curtains, drapes, napkins, and wiping cloths are being made Rayon or synthetic staple, as well as cotton, are being employed. Processing methods, which vary among the different manufacturers, have not been disclosed, but in general multiple layers built up of fiber webs are run through a chemical bath and then given a heat treatment which bonds them together to form a thin sheet or fabric

Knitting Altough warp knitting is not a new art, its possibilities for producing low-cost fabric have been realized only since modern advances in techniques. The chief center of interest has been the tricot machine (75-79), which appears likely to outrank other types of warp knitting machines, except perhaps for certain end uses to which the latter are especially adapted.

It was not until 1946 that much attention was drawn to the tricot method; indeed, the fact that knitted fabrics without stretch could be produced on the tricot machine was a secret until 1947. In the United States the American Viscose Corp. pioneered with the Aveco machine, which operates at about 500 courses per minute and is built in 168-inch width. The much publicized F.N.F. Machine (76-78) recently developed in England and first demonstrated in the U. S. by the American Viscose Corp., as an 84-inch machine operating at 1,000 courses per minute.

Thus far use of the tricot machine has been confined principally to fine-count yarns. The most popular tricot fabric today is rayon jersey for women's dresses, and it is widely use also for undergarments. Considering the extremely high production possible with this machine, which requires lower capital investment and lower cost of labor for the same yardage obtained from looms, one is inclined to speculate on the possibilities for competition with the loom.

Wet Processing and Finishing

Continuous Processes. Conspicuous among the important advances in textile manufacturing has been the success achieved in continuous processes designed to replace conventional batch methods for large-scale operations. Stimulated by the necessity for increased production and saving of manpower, some designs were completed and installations were made during World War II through a three-way cooperation between mills, research staffs of large chemical manufacturers, and machinery builders. Although the primary purpose of wartime installations was not to effect economies in operations, the notable savings in chemicals and steam, as well as in labor and in floor space, attracted wide interest. A number of machine builders have recently added continuous ranges to their lines and the textile industry has been actively engaged in improving existing processes and adapting continuous methods to other steps in finishing operations.

One of the most recent articles on the subject (80) discusses the two general types of finishing ranges used for cellulosic fabrics: the continuous cloth-preparation range and continuous dyeing Schematic diagrams illustrate the Du Pont, the Becco, and the Williams systems. And in an earlier article (81) the basic principles of several systems are outlined. Although the first continuous bleaching systems handled cloth only in rope form, designs for open width are now in use Combined all-purpose ranges have so far not been attractive commercially (82). In the operation of a typical range, many advantages over the old kier-boiling method have been demonstrated (82, 83) The mill which recently installed the first system using sodium peroxide instead of hydrogen peroxide considers the quality of the bleach to be equal to that achieved by the kier method (84) Incidentally, installation of automatic controls to the J-box effected an additional saving of 40 per cent in steam consumption McNab's general discussion (85) of the subject of bleaching compares British and American methods.

A new development is a range for bleaching knit goods continuously that requires a total elapsed time of 1.5 hours instead of the overnight period necessary in the kier system (86).

In the field of dyeing, application of vat colors by a continuous process has not only increased production and reduced costs but has provided a simplified method which is ideal for dyeing cotton and rayon, either straight or in mixed-fiber compositions. By certain modifications, sulphur colors have been applied to cotton with outstanding success. In this development the Du Pont Company has pioneered (87, 88), as it did in continuous bleacing (82) and, early in the war, in continuous indigo dyeing of woolen piece goods (89). Other systems have come into use (80) and one of these, the Williams system (90), which differs in some particulars from the Du Pont, is also constructed for scouring and bleaching as well as dyeing.

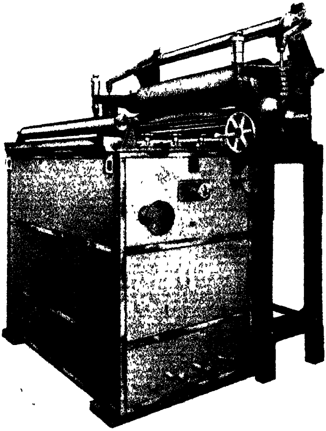
In at least one instance continuous dyeing has been applied to warps with a continuous dyeing slasher (91). And recently the representative of a manufacturer of finishing machinery predicted (92) the successful application of present-day vat dyeing to cotton and rayon warps, as well as continuous rawstock bleaching, and the advent of more versatile machinery which could be easily changed or converted to suit changing chemical requirements

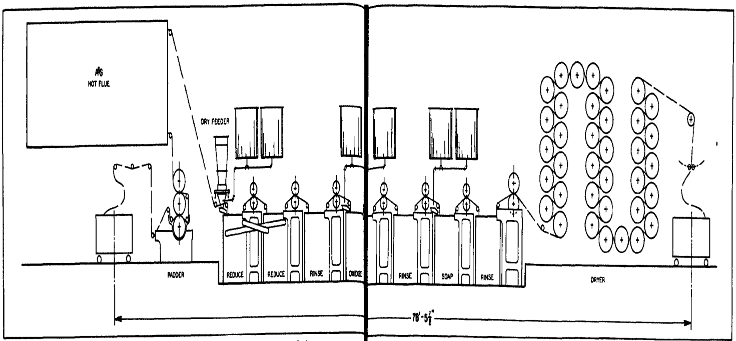
Except for dyeing of indigo referred to above (89), woolen cloth dyeing as a continuous process has not been successful. However, a successful installation for continuous dyeing of indigo on wool raw stock was made about the same time (93), and the field of woolen operations has not, by any means, been neglected. Continuous cloth carbonizers were in universal use long before World War II, and continuous cloth washers went into commercial operation during the war (94, 95). There is now a continuous fulling machine for woolen piece goods (94-96), and also a successful continuous dry-cleaning process for mill use. The experimental work on the latter was described in 1939 (97), and the process was later reported to be in successful operation (94).

Fully automatic flame singeing machines have lowered labor costs and reduced cloth spoilage (98). Other improvements on various types of processing machinery have resulted in more efficient operation (99).

Progress in Chemical Processes Although progress in the chemical phases of processing has kept in step with machine development, much fundamental work remains to be done—on the application of dyes and on sizing, for example. In fact, many problems in dyeing the newer synthetics remain unsolved. On the other hand, gratifying results have been attained in the application of pigments in dyeing as well as in printing. It is also reported that in England a colloidal dye has been per-

This unit employed in the Williams system provides continuous dyeing ranges.





A complete, all-purpose continuous dyeing range, composed of seven units, is illustrated by the Williams system.

fected which is forced into the fabric by high heat together with pressure produced by means of molten metal in the dye bath (100, 101).

New synthetic detergents and wetting agents have assumed considerable importance in wet processing operations (102, 103), and a recent article (104) presents the chemistry and applications of anionic, cationic, and non-electrolytic types.

Drying. New tenter-frame developments are not only speeding up operations but also are making it possible to dry cloth to the correct moisture content without overdrying and without danger of overheating the cloth even when air temperatures as high as 350 deg. F. obtained by means of high pressure steam are used. Overfeed tenters with overdrive gear arrangements permit increases in speeds as high as 40 per cent above the normal chain speed and with an added flexibility which will accommodate different fabric requirements (105). An overfeed tenter especially suited to the finishing of resin-tested fabrics, developed in Scotland, is being made by an American manufacturer. Improvements in air driers as well as cylinder-type driers, together with new drier designs for special purposes, have added much to the efficiency of drying operations in general.

A textile drier developed by the Western Electric Co. for drying textile-insulated copper conductors wound on large drums seems to offer definite advantages over present methods for drying some classes of textiles (106). In this system, alternate applications of vacuum and breaking of the vacuum with dry air, coupled with vigorous air circulaiton through the oven during the air cycle at atmospheric pressure, is the basis of the drier.

Use of radiant heat (infrared) has aroused much interest and a number of commercial installations have been made in textile mills. Rabold (107) describes typical installations employing batteries of lamps for drying warps and cloth. Gas-fired units are also in use. The mechanism and rate of drying by infrared and also by convection have been studied by Wilhelm and Paul (108, 109), whose findings indicate no appreciable change in drying rates when infrared is employed instead of hot air as the energy source, although theoretical equations differ somewhat (e.g., the classical wet-dry bulb relations do not hold). The main advantage of infrared seems to be its ability to obtain tremendous—if expensive—heat fluxes, thus allowing for booster units. There are no extensive data indicating effects of temperature damage to textile fibers and yarns from present drying methods; if, however, it does exist, then infrared's rapid-drying potentialities might become important.

Wilhelm's second paper deals with a method of measuring infrared energy penetration as a function of type of yarn and fabric construction. From such data, fractions reflected, absorbed and transmitted may be calculated.

Dielectric heating because of its expense has thus far been limited to special operations such as setting twist in yarns (110) and package drying, although its possibilities are being actively studied. A report by Rusca (111) is especially worthy of note since it is the most comprehensive study relating to textiles that has appeared up to this writing. It summarizes the factors to be considered in the application of dielectric heating to cotton textiles and gives a preliminary report of research under way at the Southern Regional Research Laboratory, U. S. D. A., on dielectric heating applied to cotton yarns and fabrics. Another article (112) discusses costs and methods for computing them.

Instrumentation for Process Control. The principal advances in recent years in the development of control instruments for textile mill operations, some of which employ principles of electronics, have been for application to finishing processes. Automatic control of such process variables as chemical concentrations, pH, steam flow, water flow, temperature, and moisture are essential not only to the successful operation of continuous processes but they effect savings which alone justify the considerable cost of complete instrumentation. Recent issues of the technical literature have reviewed progress in instrumentation (113-115). One article describes in detail a typical installation (116) and another (117) discusses the mathematical principles underlying the operating of a system.

DEVELOPMENTS IN FINISHES

Presented with a profusion of new products (118)—resins, softeners, detergents, special finishes, proofing treatments, and what-have-you—each clamoring for individual attention, the textile finisher has made rapid progress in improving textiles (119-122).

Of particular significance are new developments in durable finishes such as those which make fabrics shrink-resistant, crease-and muss-resistant, fire-resistant, water-repellent, etc. In a recent address (123), Powers maintained that finishing had reached the point where "the finish and not the fiber is the important factor." Over-emphasis, perhaps, but it serves to demonstrate that by application of the proper treatment it is possible to obtain a similar end-effect on two fabrics, each of them constructed from a different type of fiber with different physical characteristics.

The special properties imparted to fabrics by finishing operations may be solely, or at least in part, due to treatments given to the fibers or the yarns from which the fabrics are constructed. Nowhere in textile manufacture are developments in plastics playing a more important part than in finishing (124, 125). They may be polymerized within the fiber itself and become an integral part of the structure or they may be bonded on the surface. Or properties not hitherto present in the fiber may be added by chemical treatments which change the surface characteristics or even alter the molecular structure. In fact, developments have been so numerous that it is possible here only to give a few as illustrations.

At the Southern Regional Research Laboratory of the U. S. Department of Agriculture cotton has been modified by partial acetylation (126), a process which makes it resistant to rotting and mildewing and more resistant to heat. Cotton and rayon fabrics may be modified by direct treatment with cellulose solvents to reduce shrinkage, or cellulose in solution, acting as a carrier for clays or insoluble pigments, may be precipitated onto the surface of the textile for special effects (127). Harris (128) has built new cross-linkages in the wool fiber which make the wool highly resistant to attack by moths and other agents which commonly damage it. From Germany after the war came a report (129) of a successful treatment for mothproofing woolens which now is being adopted here.

During the war the Army's needs for water-repellent clothing brought about extensive research on the subject and some effective treatments resulted therefrom. A number of test methods were devised in order to provide means for evaluating in the laboratory the water-repellency of fabrics. Army developments have been decribed by Simpson (130) and a comprehensive survey of chemical methods is being published (131).

Stabilizing Treatments

Wool. The most talked of developments in finishing treatments today are processes for stabilizing or shrinkproofing textiles (132). Shrinkage in laundering and in wear, an age-old problem, became of acute significance in World War II because of the extent of military operations. Although the British were using dry chlorination for treating socks and underwear, and a few commercial processes were in limited use, none of them answered the problem of shrinkage control on the Army's big item, the cushion-sole sock, nor were immediately adaptable to existing machinery in American mills. How the Army solved its immediate problem and the savings therefrom have been outlined (133) and the official report (134) of the research conducted under the sponsorship of the Research and Development Branch, U. S. Army Quartermaster Corps, has been released.

Shrinkage control of woolens is complicated by the fact that a treatment that may be adequate for a woven fabric may be inadequate for one of knitted construction; or one may serve for a sock that may not be satisfactory when applied to a sweater. It has been shown, for example, that such factors as knitting stiffness, wool quality, and twist and fold of yarns influence shrinkage (135).

Some attention has been given to the effect of chemical alterations in the molecular structure of the wool fiber in reducing the tendency of woolens to shrink. Harris (136) has reported a new method for conversion of the unstable disulfide bonds to a more stable form. This is accomplished in a single bath containing a reducing agent and a rebuilding agent such as ethylene dibromide. This treatment holds considerable promise also for the reprocessing industry as a means of stripping the color from dyed woolens with minimum damage. Speakman, in England, has concluded that the resistance of a wool fabric to shrinkage when treated with a solution of mercuric acetate is due to change in cross-linkages within the fibers (137).

Much study has been given to the peculiar tendency of wool fibers to creep or crawl when rubbed together—a phenomenon known as *directional frictional effect* (D.N.F.)—as one of the principal factors influencing the felting properties of woolen fabrics, and hence many shrinkproofing treatments are based on reduction of the D.N.F. However, it has been pointed out that reduction in felting alone does not eliminate shrinkage due to stress and relaxation. In fact, reduction of shrinkage has been obtained without affecting the D.N.F. (138). Although the scales on wool fibers undoubtedly contribute to their tendency to migrate in a rootward direction, Martin (139) whose findings were later confirmed by Lipson and Howard (140), doubts that the angle of the scales producing a ratchet effect is as important as their surface characteristics. However, experiments by Mercer and Makinson (141) led these workers to conclude that the frictional difference must be due to the ratchet effect. It is clear that the nature of the felting process is still a controversial subject.

One group of investigators (142) has built up polymers in the reactive side-chains of the wool fiber, thus forming a film, essentially protein in nature, which prevents fiber movement and causes local adhesion.

Rapid progress has been made in the development of commercial shrink-proofing treatments. These fall into four main classes: halogen treatments (133, 134, 143-145) including chlorination and bromination (the U. S. Army's process employs controlled wet chlorination); alcohol-alkali treatments (146); resin treatments (147-149); and treatments by enzymes (145, 150). A treatment (144) employing halogen compounds under oxidizing conditions, developed in England, has been licensed to Cluett, Peabody & Co., who are to promote its use in the United States and Canada. It is said to be applicable both to woven and to knitted fabrics.

Cotton and Rayons. Although it has been possible to produce cotton fabrics which shrink very little by preshrinking them or by other mechanical methods such as, the famous Sanforizing process developed a few years ago, making washable rayons has remain a major problem until quite recently because of the shrinkage factor. Chemical treatments are now in commercial use for control of both cotton and rayon fabrics, to the extent that they will withstand repeated launderings.

The causes of dimensional instability in cellulose fabrics are ably discussed by Landells (151), who describes methods for producing stability through chemical modification. Creegan (152) likewise deals with the problem of shrinkage in rayons and the application of some of the new processes, the most recent of which are the Sanforset (glyoxal) process (153) and the Definized Process (152). Processes employing synthetic resins are also being successfully applied (147, 148). Dimensional stability may be achieved by means of proper blending of fibers. As an example of this, Taber (154) has reported that a blend of saponified acetate (such as Fiber B) with cotton produced a shirting which after 24 launderings shrank only 6/10 of one per cent in the warp and zero per cent in the filling. The presence of the acetate reduced the swelling characteristics of the mixture to a minimum.

Flameproofing Treatments

The increasing number of tragic accidents caused by clothing catching fire has started a wave of legislation intended to regulate the sale of flammable fabrics, and in California a law already is in effect which requires that fabrics pass a certain flammability test 155). In recent addresses (156, 157) the speakers described the situation and told what is being done by various groups to develop effective and durable flameproofing treatments and practical test methods. Extensive research was carried out during the war on combating fabric flammability and much progress has been made in the development of flameproofing treatments for textiles. This work has been so well surveyed and the whole subject of flameproofing has been so well covered by a staff of specialists in a book (158) which appeared late in 1947 that it is unnecessary to discuss the subject further in this article.

DEVELOPMENTS IN TEXTILE EDUCATION

New Concepts in Textile Education

In view of the rapidly increasing complexity of the textile industry in all of its aspects, the ten textile schools of the United States for several years have been making an earnest effort to revise and revamp their curricula, course content, and over-all philosophy of teaching. In many cases this means less emphasis on the strictly vocational aspects of the textile industry, adding to the mills themselves and to the few vocational textile schools in the country the job of completing the training of employees to operate machines or to become textile mechanics. It means that the textile graduate should have a broad college education coupled with a technical knowledge of the industry, so that he will be better fitted to meet the demands that will be made upon him as a textile executive in later years. It means a greater appreciation of the fundamental and applied sciences. It means a knowledge of business methods and of personnel management. Thus, textile education is moving rapidly farther away from the old English concept of exclusive vocational instruction, which began in the middle of the last century and drifted with minor changes far into the current one.

For the shaping of this modern education program which is being geared to the present and future needs of the industry, much credit belongs to the National Council of Textile School Deans organized under the sponsorship of The Textile Foundation (159) Meetings are held twice a year and close contact between the Deans is constantly maintained.

Foundations

That the textile industry is fully cognizant of the value of textile trained men is vividly illustrated by the fact that several textile foundations have been established within the last four or five years, the sole purpose of which is to raise funds to increase the usefulness of the textile schools over the country (160-163) Such foundations have been established in North Carolina, South Carolina, Georgia, and the New England states, and in these four areas something over three million dollars already has been obtained These funds are being used in various ways, depending upon the policies of the individual organizations, but perhaps one of the most important uses is that of supplementing salaries for teachers so that highly qualified men can be attracted to these positions

Building Programs

New building programs for textile schools are also under way (164-167) At the Georgia School of Technology, for example, a new textile building costing more than $1,000,000 is now under construction; at North Carolina State College, an addition to the present Textile Building, together with new equipment all totalling more than $600,000 in value, are being added, the Philadelphia Textile Institute has collected more than $1,000,000 in its drive for funds to develop a completely new physical plant, and at the Lowell Textile Institute a million dollar dormitory building program is under way with the first building nearing completion, a drive for funds from the Alumni is under way for an Alumni Library Building, and a bill is pending in the State Legislature for a new Engineering Building.

These indications of the willingness of textile executives to help materially in advancing textile education are very significant in indicating the new trends of thought and the value assigned to textile education.

Number of Students

Currently, some 3,600 students are now enrolled in textile schools of college level throughout this country Of course, this figure is abnormally high at the present time owing to the high percentage of veterans who are able to secure training on Government funds. Nevertheless, it is believed that the expansion in textile education is to a large extent a permanent one, and that the efficacy of these schools will continue to grow in the future

RESEARCH DEVELOPMENTS

Considerable expansion of research facilities took place during the war and this growth has continued since its close Gradual improvement in the situation governing availability of building materials and laboratory equipment has made it possible to go ahead with projects that were held up during the latter part of the war Some of the larger manufacturing organizations have established new central research laboratories fully equipped with the most modern tools, electronic devices, and scientific apparatus, and others have enlarged their laboratories as they have extended the scope of their research Sherman reports an increase of 58 per cent since 1940 in the number of companies engaged in textile research (168) Although such estimates are somewhat misleading in that they include laboratories whose principal functions are mill control and trouble-shooting, nevertheless they are indicative of the trend Two commercial laboratories are devoted entirely to textile research the Fabric Research Laboratories, Boston, established in 1942 and enlarged since the war, and the Harris Research Laboratories, Washington, which were established soon after the cessation of hostilities.

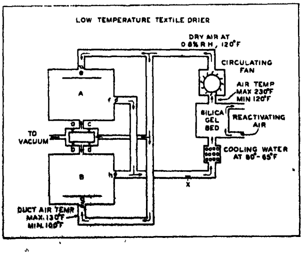
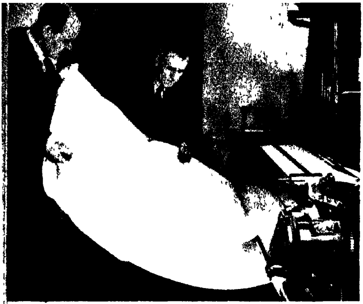

LOW TEMPERATURE TEXTILE DRIER
DRY AIR AT 0.8% RH, 120°F
CIRCULATING FAN
AIR TEMP MAX 230°F MIN 120°F
SILICA GEL BED
REACTIVATING AIR
COOLING WATER AT 60°-65°F
TO VACUUM
A
B
a
b
c
d
e
f
g
h
x
DUCT AIR TEMP MAX. 130°F MIN. 100°F

Diagram of a Western Electric low-temperature textile drier.

Detrimental effect of laundering on a woolen sock, illustrating the need for shrinkproofing treatment. The stocking shown had only three 19-minute launderings.



British are experimenting with production of a new synthetic fabric, Terylene. The fiber can be processed on spinning equipment for cotton, wool and flax.

Pipes for radiant heating are laid beneath 32-head full-fashioned knitting machine. Floors were subsequently treated with Lapidolith to prevent powdering and dusting of the concrete surface.

Industry-supported organizations have greatly enlarged their facilities and are expanding their research programs: the Institute of Textile Technology, Charlottesville, Virginia (169), supported principally by cotton manufacturing interests, and the Textile Research Institute (170) with laboratories at Princeton, New Jersey, whose membership includes organizations in all branches of the textile industry and its suppliers. The American Association of Textile Chemists and Colorists, whose research has been carried on principally through committees, in 1946 equipped a laboratory at Lowell, Massachusetts (171).

The Textile Foundation, which conducts its research in the laboratories of the Textile Research Institute under a common director of research with the Institute, has added to its research programs.

Greatly enlarged research programs sponsored by the Government are in the offing also Of these, the Agricultural Research Program, authorized under the Research and Marketing Act of 1946 of the U. S. Department of Agriculture, includes provisions for extensive research on the production and utilization of natural fibers and fibers from agricultural products (172), and a study is now under way to define the areas of research under this program and to outline methods of attack. Many projects are now being sponsored by the Office of Naval Research and by the Research and Development Branch of the Quartermaster Corps, the program of which has been defined in a recent report (173). A consolidated laboratory to house the proposed increased research activities for the last-named branch of the Armed Services, to cost almost six million dollars, is being planned (174, 175)

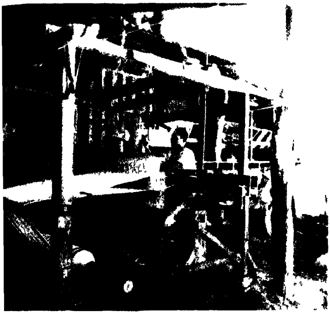
More and more emphasis is being placed on research into the structure and properties of fibers as a basis of interpreting their behavior in textile structures and of achieving greater efficiency in their use. In these studies the chemist, the physicist, the microscopist, and the engineer are engaged In his classic Marburg Lecture (176), the late Harold DeWitt Smith discussed the properties and utilization of fibers from the point of view of engineering, and more recently other investigators (177-181) have made further contributions through their studies of stress-strain-time-temperature-humidity relationships, elasticity, resilience, etc

Progress has been speeded immeasurably by new tools (182-184), employing recent developments in electronic devices, for more accurate determination of the behavior of fibers, yarns, and fabrics under stress—tension, compression, relaxation, torsion, flexure, abrasion Although improvements have been made in the design and control of conventional tensile testers (185, 186), their inherent characteristics of momentum, inertia, and friction limit their usefulness as research tools and new types using the electric strain-gage are coming into use (182, 184, 187-189). Other testers of advanced designs are in the development stage but as yet have not been reported in the literature.

Measurement of compressional behavior of textile materials by means of apparatus built on new principles is yielding valuable information (190).

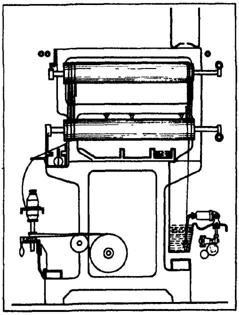
Textile fibers exhibit the phenomenon of plasticity or creep as well as true elasticity Hence efforts have been made to measure the elastic component alone. In order to measure Young's modulus, one laboratory employed sound waves of 10,000 C.P.S. frequency. The speed of propagation along a filament made it possible to calculate that modulus (191). Sonic vibrations have also been used in the determination of linear density or denier of short fibers and filaments (192). Falling-weight impact testers in which the load can be applied to the specimen in less than 0.001 second have been used in determinations (182, 193). With this type of apparatus, properties of the material under test can be studied without interference of machine characteristics.

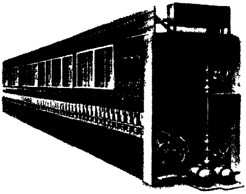
Important contributions to an understanding of fiber behavior are being made through theoretical studies of the mechanical properties of natural and synthetic high-polymers (194-196) and by chemical, microscopical, and X-ray determinations of crystalline and amorphous

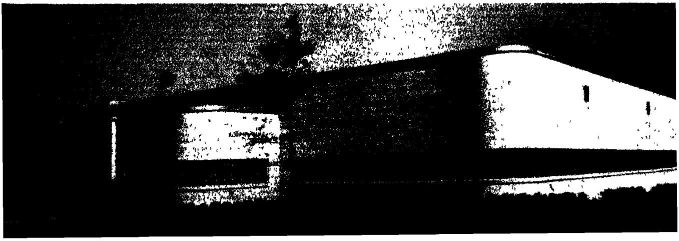


Primitive hand-weaving of clothes may still be found in some parts of Latin America.

This Sulzer loom has a small steel gripper that draws the thread from a single "cheese" of yarn, does away with bobbin winding and the usual yarn-riding shuttle. A series of guides between warps keeps the shuttle from contacting warp yarns.





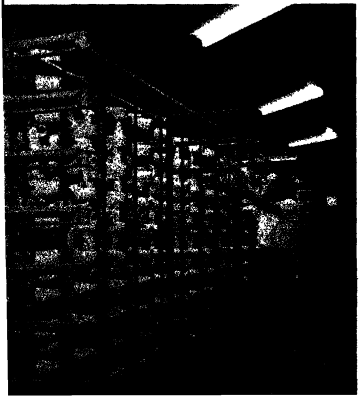


Building occupied by Sapphire Hosiery Corp., showing simplicity of modern mill design.

Proper location, adequate lighting and efficient air conditioning characterize this modern mill of the Pepperell Mfg. Co.

Tricot knitting machine installed in plant on west coast of the United States.

Creel of Reiner tricot warper.



area relationships (197-199) and their influence on the mechanical properties of fibers. It is generally recognized that fiber strength is closely associated with the degree of crystallinity. Mark (200) has indicated that the properties of maximum strength and maximum resilience of a fiber are dependent upon the degree to which the system approaches the extreme solid state or the extreme rubbery state, respectively; that fibers plastics, and rubbers are not intrinsically different materials but are only different combinations of three fundamental states in which high polymers can exist. A recent article reviews developments in the theories of the mechanical properties of rubber-like as well as fiber-like systems and also describes the authors' experimental study of the mechanical-optical properties of materials varying in nature from ideal rubbers to polycrystalline plastics (201).

Considerable interest was aroused in the Summer of 1947 by announcement (202) of the successful synthesis of protein-like molecules almost identical chemically with natural silk which were precipitated in the form of a thin film.

A modification of the currently accepted theory for the chemical structure of cellulose is proposed by one investigator as the result of his research on the degradation of cellulose by hydrolysis (203).

The *skin effect* in viscose rayon and the influence of thickness and structure of the outer skin on the fiber properties have been the subject of further study (204, 205), and surface properties of fibers in general are being investigated. Moisture adsorption and swelling are receiving consideration (206-209), since these fiber characteristics affect the dimensional stability of fabrics. Moreover, the equilibrium moisture content affects both the rate and the extent of drying. Although considerable work was done in this field some years ago (210, 211), there has existed a need for an effective generalized correlation of the data accumulated by the early researchers This correlation has now been supplied by the work of Whitwell and Toner (212). By the Othmer chart method, they established a definite linear relationship between sorption and desorption for all textile materials for which data were available, providing a means of obtaining reliable data on the moisture-content relative-humidity relations of a textile or other adsorbent material over a range of temperatures, and from only a few careful measurements.

Studies on the fundamental elements involved in sizing are under way, including such factors as the dynamic resilience of yarn, rheological properties of starch and gelatine sizes, pickup of sizing as affected by several variables, and friction of sized yarn. The mechanism of detergency is being studied and some early reports have appeared (213, 214). Research is in progress on various causes of damage to textiles such as the action of light (215), attack by microorganisms (216, 217), and degradation by other agencies (218). A comprehensive review of work on the subject of microbiological deterioration has recently appeared (219). The action of ozone in varying concentrations, such as those which may be encountered at different locations and at different altitudes, is being studied.

Fundamental research on the mechanism of dyeing, particularly with respect to the new polymerized fibers, is being initiated. The application of amino groups into cotton fabrics has imparted to them the property of dyeing readily with acid wool dyes (220). Ultrasonics (vibrations of frequency above that of audible sound) are being explored as a possible means of improving the stability of solutions or of making solutions of materials hitherto considered to be incompatible, and also in the application of dyes (221, 222). There have been significant developments in the use of reducing agents to remove color from dyed woolens, one of which has already been mentioned (136) The other process (223) employs an electrolytic preparation of the stripping solution, the stripping power of which is maintained constant by re-circulation and re-energizing and can be so controlled that deposition of reduction products is kept at a minimum. The process is said to strip chrome and vat colors which do not yield to other processes and to hold losses in strength of the textile below 10 per cent

Emphasis is being placed on the relationship of fiber properties to those of yarn and fabric, and considerable attention is being given to devising laboratory test methods which will correlate with actual performance in wear A significant advance in the field of wear testing has been made by the design of an abrasion machine which will abrade a plane area of a specimen uniformly over the entire area and from every direction in the plane (224). The application of geometry to functional design of fabrics has been studied by Peirce (225)

Progress has been made in utilizing modern techniques to study textile machinery in operation. The cathode-ray oscillograph shows promise as a research tool in the development and improvement of textile machines and in the study of loom vibrations, picking timing, etc (226) The electric strain-gage has also been applied to the study of the loom (227), as has high-speed photography (228)

Only a few of the many research activities have been mentioned, but these will serve to indicate the broad extent of research that is in progress

CONCLUSIONS

It would be well to point out that it is still too early to evaluate more than a few of the developments which are appearing in a steady flow throughout the entire textile industry and its allied branches. At any rate, it is certain that the situation which prompted the oft-repeated charge that the textile industry was one of the most backward in its research and technology no longer holds The industry now is introducing developments faster than it can digest them and only time will furnish a true perspective in this renaissance. Realization of the need for scientific investigation is gradually taking hold on the textile industry. In no other industry is it of greater importance for from it come the building blocks upon which rest technological developments Without the continued contributions of science it is obvious that, in time, applied research in textiles will find itself short of food.

Illustrations for this chapter were obtained through the courtesy of various manufacturers whose pictures and materials were used by the Textile Research Institute.

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